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STRUCTURE OF THE CARBONDALE RIVER AREA ALBERTA

W.H.A. CLOW

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C A R B O N D A L E R I V E R A R E A

A DISSERTATION

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

FACULTY OF ARTS AND SCIENCE

by

WILLIAM HENRY ARTHUR CLOW, B.SC.

EDMONTON, ALBERTA

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TABLE OF CONTENTS

Page

CHAPTER 1

INTRODUCTION

Location, boundaries and access 1
Previous work in the region 3
Present work 5
Acknowledgments 7

CHAPTER 2

GENERAL CHARACTER OF THE REGION

Topography 9
Drainage 10
Culture 12
Fauna and flora 12

CHAPTER 3

STRATIGRAPHY

General statement 15
Precambrian formations 16
Paleozoic formations 17
Mesozoic formations 17
Jurassic 17
Fernie formation 17
Name, distribution, age and correlation 18
Lithology and thickness 19
Table of Formations 20
Cretaceous 24
Lower Cretaceous 24
Kootenay formation 24
Name, distribution, age and correlation 24
Lithology and thickness 25
Blairmore formation 25
Name and distribution 25
Thickness and lithology 26
Age and correlation 27
Crowsnest formation 27
Name, distribution and thickness 27
Lithology and age 27

Page

Upper Cretaceous 28
General statement 28
Blackstone formation 28
Lithology, thickness and age 28
Bighorn formation 29
Name, distribution and thickness 29
Lithology and age 29
Wapiabi formation 30
Name, distribution and thickness 30
Lithology and age 30
Allison formation 31
Distribution 31
Thickness and lithology 31
Age and correlation 32
Bearpaw formation 32
Pleistocene and Recent 32
Competency of formations in the Carbondale River Area . 33
Definition 33
Precambrian and Paleozoics 34
Mesozoics 34
Jurassic 34
Lower Cretaceous 34
Upper Cretaceous 35

CHAPTER 4

REGIONAL ROCKY MOUNTAIN STRUCTURE

General statement 37
Rocky Mountain structure of Montana 38
Structure of the Flathead valley 40
Structure of Crowsnest Pass Area 42

GEOLOGICAL STRUCTURE WITHIN CARBONDALE RIVER AREA

Introductory statement 43
Structure of the upper Carbondale River area 43
Structure at the headwaters of Lynx and Lost creeks . . 47
Structure of the Mesozoics south of Carbondale river and under the main overthrust 48
Willoughby Ridge and Cherry Hill 48
Maverick Hill and Maverick Hill fault 50
Carbondale Hill structure 52
Anticlinal structure of Ginger Hill 54
Backus Mountain thrust 55
Turtle Mountain anticline 56
The main thrust fault 57
The Lewis thrust 59

Page

CHAPTER 5

SUMMARY AND CONCLUSIONS 63

BIBLIOGRAPHY 66

Figures

Figure 11 and map in envelope at back

CHAPTER I

INTRODUCTION

Location, Boundaries and Access

The map-area herein designated as the Carbondale area within lies in the foothill and mountainous district of southwestern Alberta. It is located seven miles south of Blairmore, which is an important coal mining centre in the Crowsnest Pass, and about fifteen miles west of the town of Pincher Creek. The map-areas adjoining are Blairmore (Leach, Rose, 1920) on the north, and Beaver Mines (Hage, 1940) on the east. Excepting for ten and one-half square miles in the northeast corner, the map-area is within the Rocky Mountains Forest Reserve. The portion south of the Carbondale river lies within a game preserve. The Carbondale River map-area lies wholly within the territory drained by the Castle and Carbondale rivers, both of which are tributary to the Oldman river.

The northern boundary of the Carbondale River map-area is $49^\circ\ 30'$ north latitude and the eastern boundary is $114^\circ\ 15'$ west longitude. The area is confined on the west by the British Columbia-Alberta boundary. The southern boundary is the northern limit of the Precambrian overthrust, which traces a sinuous path through the northern portion of township 4 and the southern part of township 5.

Three main roads serve the area. One branches from the Crowsnest highway at Bellevue, another forks south from the same highway at Burmis post office and a third travels west from Pincher Creek. The first mentioned is for the greater part a private road. This route passes through Hillcrest and follows along the valley of Byron creek and past the Adanac coal mine to the summit. From thence it follows the valley of Webb creek to the Carbondale river, descending 1300 feet in so doing. It proceeds up the Carbondale valley and branches out to the various lumber camps on O'Hagen and Gárdiner creeks and the Carbondale river. This road is kept in good condition and is passable even under severe conditions of rain or snow. The road branching from Burmis proceeds south to the Castle river, follows up the Castle to its confluence with the Carbondale river and at this point forks. One fork joins with the first mentioned road while the other fork follows up the Castle river to the Castlemount ranger station where it trifurcates, two branches continuing along either side of the south fork of Castle river and the other following the west branch. The main road from Burmis is usually rough but was passable at all times. The third road, which is from Pincher Creek, follows along Beaver Mines creek to about three miles southwest of Beaver Mines post office. At this point the road bifurcates, the right branch passing over a low summit to join the Burmis road at the Castlemount ranger station. Many smaller roads, some of which are still passable,

have been built for lumbering operations.

Pack trails, in the northern part of the area, follow along the main creeks. This portion is not accessible by road. There are trails along Lynx creek and its branches, along Lost creek, and along Carbondale river. This last one commences at the termination of the road at the Burmis Lumber Company camp and continues west along Carbondale river to its headwaters, then through North Kootenay Pass into British Columbia and to the Flathead valley. These pack trails have not been kept in repair, it being necessary on all of them to cut out windfall and detour slideouts and marshes that had been corduroyed many years before.

A pack train was used for 41 days during which time approximately one third of the area was covered. In surveying the remainder an automobile was used.

Previous Work in the Region

The first records of the geology of the southwestern part of Alberta were made by Dr. J. Hector (Hector, 1863) who did the geological mapping for Captain J. Palliser's expedition. Hector did not visit the mapped area, but Palliser and his secretary journeyed through North Kootenay Pass on returning to Edmonton from British Columbia territory. G. M. Dawson (Dawson, 1885, 1886) made a preliminary survey in the area. He traversed the area from the east side of the present map-area to the summit

of North Kootenay Pass. His observations include a description of coal seams, volcanics and a summary of the structure of the region. R. C. McConnell did work in the region, particularly that of dividing the rocks into formations (McConnell, 1887). D. B. Dowling worked in the Cascade coal basin (Dowling, 1903, 1904) and also made a compilation of the coal reserves of Western Canada. R. A. Daly (Daly, 1912) surveyed and described the formations and structure along the forty-ninth parallel.

The area immediately adjoining the Carbondale area to the north, due to its importance as a coal field, has been thoroughly investigated. W. W. Leach (Leach, 1905) was one of the first to examine it. Leach surveyed the coal field in 1911 and 1912 and published stratigraphic and structural reports together with a preliminary map (Leach, 1911). The Flathead coal field, lying in British Columbia, immediately west of the Flathead and Clarke ranges, was surveyed by J. D. MacKenzie in 1912. In the same year he made a preliminary survey of the present area which at that time was known as the South Fork area (MacKenzie, 1912). Leach's work in Alberta was continued by B. Rose, (Rose, 1915), who published a detailed geological map of the Blairmore map-area. This was followed in 1916 by a report on the stratigraphy and structure. In 1915 F. H. McLearn investigated ~~and wrote an account of~~ the Jurassic and Cretaceous of the Crowsnest Pass (McLearn, 1915). He later published a bulletin describing the

Mesozoic paleontology of the region (McLearn, 1929).

Later G. S. Hume, B. R. MacKay, Pierre de Bethune and Robin Willis contributed reports on the areal and regional geology. Hume has contributed particularly to our knowledge of the structure of the area by his observations in the North Kootenay Pass (Hume, 1932). MacKay worked in the Crowsnest Pass area from 1930 to 1932, and has described in some detail the stratigraphy and structure with special attention being given to the coal measures and coal mines. Pierre de Bethune, geologist with West Canadian Collieries, described the structure of the Rocky Mountain ranges adjacent to the Flathead and Elk River valleys (Bethune, 1936). R. Willis and B. R. Hake working for private interests compiled a map of the region.

P. S. Warren has described the rock sequence in the Crowsnest Pass (Warren, 1933), and has also surveyed and described the Fernie formation in the region, particularly in the Fernie basin (Warren, 1931, 1932, 1934). In 1948 M. B. B. Crockford spent several days in the area making reconnaissance surveys, preparatory to detailed surveys which were being considered for 1949.

Present Work

Survey of the Carbondale River area was planned and carried out during the 1949 summer season. This area was chosen because of the possibilities of economic recovery of coal from

the Kootenay strata, because Kootenay coal seams which extend into the area are mined economically in the north.

Monuments and survey lines, established by the Dominion Government early in the century, were used to some extent to establish horizontal control, although most of the cut lines have been obliterated by forest fire and regrowth of timber. Further horizontal control was obtained by the use of aerial photographs and reference to timber maps of the Burmis Lumber Company.

Topographic control was obtained from the Department of Interior maps of the Crowsnest Forest and Waterton Lake Park, sheets 3 and 4.

The amount of stratigraphic information obtained by the survey was disappointing. This was due in part to the wide extent of the glacial mantle, the density of forest cover, and also to the tremendous amount of earth movement to which the strata had been subjected. During these movements the rock formations were faulted and folded so many times that sections of more than a few hundred feet are rare. On the other hand the area offers a wealth of material for structural studies.

Stratigraphic sections were measured by steel tape, step method and plane table. With the exception of the Crowsnest, Kootenay, Blackstone and Cardium it was not possible, due to the faulting and scarcity of outcrop, to obtain any complete section of a particular formation.

The party was under the supervision of Mr. M. B. B. Crockford, Chief Geologist, Petroleum and Natural Gas Conservation Board, Province of Alberta. The writer had charge of the field party.

Acknowledgements

Capable assistance was given in the field by D. E. Duff and G. L. Colborne, student assistants, R. Sharp, packer and G. F. Wyatt, cook. S. J. Groot, draftsman for the Research Council of Alberta, prepared the accompanying map.

P. S. Warren spent five days with the field party during the summer and gave valuable guidance and direction.

The courtesies extended to the party by T. Van Wyck, J. L. Stevens and V. Patinaude of the Burmis Lumber Company, F. Jones, W. Walliter and Robin Huth of the Alberta Forestry Service and J. A. Brusset, H. Gardiner and N. Melnyk of the West Canadian Collieries are greatly appreciated.

M. B. B. Crockford, Chief Geologist, Petroleum and Natural Gas Conservation Board has given much appreciated assistance in field work and the preparation of this report.

The preparation of this thesis has been under the direction of Professors P. S. Warren and R. L. Rutherford, Department of Geology, University of Alberta, who have directed and offered valuable criticism.

Thanks is extended to the members of the Department of

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The summer field party and the writing of this thesis have been under the auspices of the Research Council of Alberta.

CHAPTER II

GENERAL CHARACTER OF THE REGION

Topography

The Flathead range, the southern portion of the front Rocky Mountain ranges lies on the west of the area. It has a north-south trend which is also the regional trend of the Rocky Mountain ranges. Peaks of the Flathead range are the highest of the area; and one of them, Mt. Darrah, is 9038 feet high (Figure 1).

Clarke range to the southwest of the area has a regional and local southeast trend. Syncline Mountain in this range has an elevation of 8008 feet.

The ridges formed by the upheaval and subsequent erosion of the Mesozoic rocks strike in a northwesterly direction within the area. Those ridges north of the Carbondale river have a trend 20 degrees west of north; whereas south of the Carbondale river the general strike changes to about 55 degrees west of north. Erosional processes have caused the ridges to become very irregular in shape. Some portions are eroded to near valley level while in other places they rise to become prominent hills. The highest of these hills are Prospect hill, elevation 6400 feet; Cherry hill, elevation 6300 feet; Carbondale hill, elevation 5921 feet and Backus mountain, elevation 5924 feet. These elevations are approximately 900 to 1000 feet above the general level of the terrain.

Broad valleys lie between the ridges or are normal to them. These valleys have been formed by stream and ice action. That main stream valleys have been heavily glaciated, is exhibited by their U-shape and the large amount of glacial debris found in them. Moreover, more than one stage in the ice advance is shown along the valleys, especially those of Lynx creek and Carbondale river. Three main terraces were observed in each of these valleys. These terraces suggest damming of the ice causing the accumulation of sediments. The three main levels are evidence for three different lake levels and thus three different periods of damming. The valleys lying between the ridges and having the same trend as the ridges are largely the result of differential erosion of the inclined strata by subsequent streams.

Drainage

The drainage of the Carbondale area is tributary to the Oldman river. The two main streams are the Castle and the Carbondale, the latter being tributary to the Castle and flowing into it in the northeast corner of the mapped area. Early geographical accounts called the Carbondale river the South fork and the Castle river the Little fork. The whole area was referred to as the South Fork country.

The Carbondale river has its source in two small tandem lakes about a half mile from the summit of North Kootenay Pass. It

flows in an easterly direction to its confluence with the Castle. Four large creeks, Gardiner, Lost, Lynx and O'Hagen are tributary to it. These creeks, with the exception of O'Hagen, have their sources in cirques of the Flathead and Clarke ranges. Lost creek has at its headwaters four large cirques, and Lynx creek three at the source of its west branch. O'Hagen creek rises from small tributary streams which drain the rolling tract between Gardiner creek and the Castle river. Castle river rises in the Clarke range some distance south of the map-area. The west and south branches of Castle river join at the site of the Castlemount ranger station. The main river flows from this point through the map-area in a northwesterly direction. These streams and their tributaries provide the drainage for the southeasterly portion of the territory.

All of the streams mentioned in the above description are antecedent for the major part of their courses. Occasionally they become subsequent if they pass from resistant to weak strata. This is illustrated on George and Lynx creeks where the creeks are incised in the soft arenaceous shales of the Blackstone formation, which lies adjacent to the more consolidated Crowsnest volcanics. Moreover, many of the smaller tributary streams follow the trend of the ridges to their confluence with the creeks. George creek, a tributary of Lynx creek, follows the Blackstone-Crowsnest contact for the larger part of its course.

No difficulty is encountered in crossing these streams

during the summer months, it being unnecessary at any time to wade over knee depth. It is possible in many cases to cross them on fallen timber.

Culture

The map-area does not support any community centres. The lumber operators have established semi-permanent camps which are moved from time to time, their site being dependent upon the operational area. The largest of these camps is that of the Burmis Lumber Company, and is located in section 28, township 5, range 4, west of the fifth meridian. This camp has several temporary family dwellings, a school and a commissary. There is a ranger station at the forks of the Castle river and another at the junction of Lynx creek and Carbondale river. A fire lookout is situated on Carbondale hill. There are several small ranches in the north-eastern and the eastern portion of the map-area.

Two cabins, one on the north branch of Lost creek and the other just east of the junction of the west and north branches of Lynx creek, are used by trappers and hunters.

A strip coal mine owned by West Canadian Collieries is in operation on the ridge lying between George and Webb creeks, (Figure 2).

Fauna and Flora

Although the southern portion of the map-area lies within

a game preserve and the northern portion is fairly inaccessible to hunters, wild life is not abundant. Black and grizzly bears are present but not in great numbers. Only a few moose, elk, deer and mountain goats were observed, and it is concluded that the animals do not inhabit the area in large numbers. Of the smaller animals Columbian ground squirrels and coyotes are the most abundant, while red squirrels, chipmunks, conies, beavers, porcupines and weasels occur in lesser numbers. The streams offer very good trout fishing. Grouse are plentiful throughout the southern part of the area.

Forest growth is in parts quite dense. The entire map-area with the exception of the hills adjacent to the lower part of the Carbondale and Castle rivers and the river valleys of this same section which is grassland, are or have been heavily wooded. That sector lying between Castle and Carbondale rivers and west of Carbondale hill was swept by a forest fire in 1936, and consequently is covered with dead timber. A tree regrowth of a height of six to eight feet is beginning to appear. The fallen timber and regrowth make traverse very difficult. That part north of the Carbondale river and west of George creek excepting for a few of the ridges is very heavily wooded. The principle trees are spruce, balsam and pine. Poplar occurs but is usually of a scrubby nature. Douglas fir is present in scattered clumps. The undergrowth is very thick, especially on the north and east slopes of hills and

ridges. Red cedar was found growing in clumps on the ridges between Lost creek and West Lynx creek. A varied alpine flora was observed, the flowering plants being very abundant both above and below tree line. Tree line is 6500 to 7000 feet above sea level.

Small muskegs occur infrequently in the map-area. They are confined to those sections of the river valley which are broad and flat. The upper valleys of Lynx and Lost creeks have many small muskegs.

CHAPTER III

STRATIGRAPHY

General Statement

The rocks of the Carbondale map-area range in age from Proterozoic to Recent.

The Proterozoic rocks include partially metamorphosed sediments and volcanics of late Precambrian age. Lying conformably on the Precambrian formations is a quartzitic formation which is placed in the Cambrian (Hage, 1940). The quartzitic rock is overlain by shales, dolomite and limestone of the Devonian system, and these are succeeded by Carboniferous limestones and shales.

The oldest Mesozoic strata are those that belong to the Jurassic system. The Lower Cretaceous, conformable with the Jurassic, is represented by the Kootenay, Blairmore and Crowsnest formations. This last formation is volcanic in origin, and is one of the few occurrences of rocks of this type in Alberta. The Upper Cretaceous formations are a series of marine shales and sandstones which have been divided into the Blackstone, Bighorn and Wapiabi formations, and a succession of fresh water and brackish water strata called Allison formation. The thicknesses of Tertiary rocks in adjacent territories to the east would indicate that strata of this age were at one time present in the map-area, but have been removed by erosional processes. Pleistocene and Recent deposits of gravel, sand, clay, a fairly well consolidated conglomerate and a thin soil

mantle are very prominent.

No difficulty was encountered in the determination of boundaries of formations because the lithological breaks are quite pronounced. However, the faulting and folding within formations and the thrusting of older formations over younger strata have made difficult the measurement of formational thicknesses.

PRECAMBRIAN FORMATIONS

The survey did not concern itself with details of the Precambrian and Paleozoic formations. Casual observation of the Precambrian rocks led to the conclusion that the oldest rocks present are those of the Siyeh formation, which is represented in the area by thin bedded argillaceous limestone, cryptozoan limestone, and a sill of basic igneous rock identified by Hage (Hage, 1940) as a diorite. Overlying the limestones is a massive bed of amygdaloidal basalt, which has in it a basic layer of rock containing numerous laths of feldspars. The feldspar crystals show very distinct zoning. The remainder of the strata lying between the above mentioned igneous bed and the Cambrian is largely red argillite with a sill of basic rock near the Precambrian-Cambrian contact and are considered to belong to the SHEPPARD and KINTLA formations.

The total estimated thickness of the formations in the vicinity of North Kootenay Pass is 2000 feet. The peaks of the Clarke range are, within the map-area, composed of Precambrian

strata. Too, the Precambrian formations underlie the Paleozoics of the Flathead range.

PALEOZOIC FORMATIONS

The Paleozoic rocks of the area lie in the Flathead range and Turtle Mountain anticline. Overlying Precambrian rocks and apparently conformable with them is a 50-foot bed of pinkish quartzite which Hage (Hage, 1940) assigns to the Cambrian. A disconformity occurs between the Cambrian and Devonian and rocks of Silurian and Ordovician age are not present. Devonian shale, dolomite and limestone of the Fairholme and Palliser formations overlie the Cambrian. P. S. Warren has identified fossil corals, trilobite fragments, conodonts and brachiopods collected from the Devonian strata and has placed them in the Upper Devonian (Warren, 1949). The Exshaw shale, lying at the top of the Devonian, is twenty feet thick. Rocks of Carboniferous age occur above the Exshaw shale. The Banff shales were recognized and it is thought that some of the precipitous peaks are formed from Rundle limestone.

Rocks of Carboniferous age form Turtle Mountain anticline and lie disconformably below the Jurassic rocks (Figure 3).

MESOZOIC FORMATIONS

JURASSIC

Fernie Formation

Name, Distribution, Age and Correlation

In 1902 W. W. Leach (Leach, 1902) referred to the dark shales underlying the Kootenay coal measures as Fernie shales and in 1911 he formally applied this name to the same shales to which he assigned a Jurassic age.

In the Carbondale River map-area the Fernie formation occurs along the limbs of the northeastward striking Turtle Mountain anticline. It plunges out with this anticline in the valley of the Carbondale river. Two slices of the formation occur. One was observed at the headwaters of Lynx creek and the other on the Upper Carbondale.

Fossils collected from the Fernie strata are Entolium leachi McLearn, Pleuromya summissiornata McLearn, Gryphaea impressimarginata McLearn, Inoceramus obliquiformis McLearn, Protocardia schucherti McLearn, Thracia canadensis McLearn, Pleuromya obtusiprorata McLearn, Thesis sp., Lima albertensis McLearn, Cadoceras sp., and Miccocephalites concinnus (Buckman). This fauna is assigned to the Callovian (Upper Jurassic) age by Buckman (Buchman, 1929).

The zones in the Fernie formation of the Carbondale area do not wholly correspond to those more northerly sections seen in the Highwood-Elbow (Allan and Carr, 1947), Ribbon Creek (Crockford, 1949) and Mountain Park areas, in that the ~~lower~~ fauna of the Rock Creek member is absent.

Lithology and Thickness

The Fernie formation lies disconformably on the Paleozoic formations of the Turtle Mountain anticline.

The Fernie succession is largely one of a series of marine shales. The basal shale overlying the phosphatic sandstone is slightly sandy and has a very platy habit. Freshly exposed surfaces reveal plates of 1/8 inch to 1/4 inch in thickness. The dark shale overlying this is very fissile, and at this locality gave indications of flowage due to pressures exerted upon it presumably during the orogenic movements of the Rocky Mountain uplift. The thick brown shales, which overlie, succeeding the black, are a phase of the Fernie not previously observed (Warren, 1949). These shales weather to a characteristic crumbly surface. In fresh exposures the shale has a somewhat blocky habit. Nodules which occur throughout the bed were found to be hollow in the centre, and as they are of a very porous nature it is presumed that the interior has been removed by leaching. Near the top of the brown shale zone a fossiliferous horizon of arenaceous limestone occurs. This is followed by more brown shales and then green sands. The green sands were observed also along Carbondale river, and in the slice at the headwaters of Lynx creek. Microscopic examination of the sand shows it to be composed largely of glauconite. The upper portion of the formation is a series of shale and interbedded sandstone layers commonly referred to as "the ribbon sands". The sand-

Table of Formations

Group	System	Series	Formation	Character	Thickness feet
Cenozoic	Quaternary	Recent and Pleistocene		Soil, gravels, till and conglomerate	
			Erosional Unconformity		
Mesozoic	Cretaceous	Upper Cretaceous	Bearpaw	Blue grey, sandy shales with carbonaceous layers and shell beds. Marine and brackish water.	
			Allison	Soft, greenish-grey sandstones and shales with brackish water fossils. Non-marine and brackish water.	2500
			Wapiabi	Dark grey to black shales and sandy shales with concretions. Some thin sandstone bands. Fossiliferous. Marine.	1400
			Bighorn	Upper hard grey quartzitic sandstone. Conglomeratic layer and dark grey sandy shales. Lower greyish quartzitic sandstone and shale. Fossiliferous. Marine.	101
			Blackstone	Grey to dark grey shales and sandy shales. Dark, cherty conglomerate at the base. Fossiliferous. Marine.	325
			Erosional Unconformity		
			Crowsnest	Tuffs, agglomerates, breccias and bedded ash.	465

Group	System	Series	Formation	Character	Thickness feet
		Lower Cretaceous	Blairmore	Green, grey and maroon shales, grey green and greenish grey sandstones. Limestone nodules and a fossiliferous layer near the base. Large lenses of conglomerate about 700 feet from base. Hard, massive cherty conglomerate at the base. Non-marine.	1800
			Unconformity		
			Kootenay	Brown, dark grey and black shales often carbonaceous, coarse- to fine-grained, brown sandstones. Coal seams. Thick basal sandstone member. Non-marine.	280
	Jurassic		Fernie	Brownish grey sandstone at top overlying interbedded sandstones and shales grading down to brown and black fissile shales. Nodules. Black, sandy, phosphatic bed at bottom.	1035
			Erosional Disconformity		
Paleozoics	Carboniferous	Mississippian	Rundle	Limestone.	
			Banff	Limestone, calcareous shale, shale.	

Group	System	Series	Formation	Character	Thickness feet
	Devonian	Upper	Exshaw	Shale	
			Palliser	Limestone and dolomite	
			Fairholme	Dolomite, shale and limestone	
			Unconformity		
	Cambrian			Quartzites	
			Unconformity		
Precambrian	Proterozoic (Late Precambrian)		Kintla	Red, green and grey argillites, quartzites and diorite sills.	
			Sheppard	Brown argillite, limestone and sandstone	
			Purcell	Sill of dark green and purplish vesicular and amygdaloidal basalt.	
			Siyeh	Grey and greenish argillite, argillaceous limestone, cryptozoan limestone.	

stone bands are two to four inches in thickness and occur at intervals of approximately 1 to 4 feet. The shale is black, fissile and silty. Near the top of the shale and sandstone sequence, the sandstone beds become progressively thicker and the shale bands thinner until the shale disappears. This gradual change in sequence indicates continuous deposition.

Deposition of the Fernie strata terminated in a massive sandstone member. Lithologically this sandstone varies, in that it is fine- to medium-grained near the base, and has a rhythmical banding, whereas the upper part is fairly coarse-grained and without any banding. Moreover, the lower beds are more calcareous. The contact between the Fernie and Kootenay formations is chosen as being within this sandstone member at a point where the difference in lithology occurs. No unconformity is visible. Similar conditions were observed in the Ribbon Creek area, and a more detailed study resulted in this same conclusion (Crockford, 1949). As a result of detailed investigations of the Fernie-Kootenay contact in the Fernie area, C. Newmarch (Newmarch, 1949) has concluded that the contact is gradational, and that if any time break occurs at the contact, it must be slight.

The measured thickness of the section given is 1035.1 feet. This is thicker than the section at Fernie which was given by Warren (Warren, 1934) as 800 feet. The difference in thickness may be due to minor faulting and folding in the shale members,

particularly in the thick shale beds lying 300 to 400 feet above the base.

CRETACEOUS

Lower Cretaceous

Kootenay Formation

Name, Distribution, Age and Correlation

The Kootenay formation was named by G. M. Dawson (1886) and on the basis of fossil plants was given a Lower Cretaceous age. W. W. Leach (1912) and B. Rose defined the lower and upper boundaries of the formation.

In the Carbondale map-area seven bands of Kootenay are faulted to the surface. The most westerly band lies under the main overthrust fault of the Precambrian and Paleozoic rocks. A slice of the formation occurs a mile and a half east of the main thrust in the Carbondale area and a third follows along Willoughby Ridge (Figure 4). Two bands occur on the west limb of Turtle Mountain anticline and one on the east limb. These three join to form one band south of the Carbondale river. The seventh band is observed in the northeast corner of the area.

Within Carbondale area fossil evidence was not collected from the Kootenay formation. However, due to the stratigraphic position and lithological character of the rocks observed, it is correlated with the rocks of the Kootenay formation of the areas

north of Carbondale River area and also with the Nikinassin of the more northerly areas. The formation is, on the basis of fossil evidence, assigned to the European Neocomian-Barremian (Bell, 1944, 1946).

Lithology and Thickness

The basal bed of the Kootenay formation is a massive sandstone. The contact between the Kootenay and Fernie is chosen where the sedimentation in this massive sandstone changes from fine to massive bedding. At the top of the massive bedded sandstone an unconformity exists and a coal seam lies on sandstone without any gradational beds (Figure 5). From here to the top of the formation the succession is largely one of shale and coal with occasional sandstone bands. The thickest coal seam is the 14-foot seam being mined at the Adanac strip.

The formation has a measured thickness of 280 feet.

Blairmore Formation

Name and Distribution

The Blairmore formation was named by Leach in 1911 (Leach, 1912). He had previously recognized it as a lithological unit in 1902 (Leach, 1902).

Blairmore rocks and rocks of equivalent age outcrop throughout the full extent of the Rocky Mountains and foothills of Alberta. The formation is composed of hard sandstones and softer

shales. Resistance of the sandstones often produces ridges.

Blairmore strata have a wide distribution in the Carbondale area, since they have been faulted to the surface in a number of places. They are bedrock in the major portion of the northeastern part of the map-area.

Thickness and Lithology

The Blairmore rocks are a succession of greenish shales and sandstones. The proportion of shale to sandstone is greater in the middle of the formation. The shales are largely green in color, blocky in habit and unfossiliferous. Occasional beds of maroon shale occur. One 12-foot bed of fresh water limestone was observed.

Two large conglomerates occur in the Blairmore formation. The basal conglomerate is 20 to 30 feet thick. Pebbles of chert and quartzite are very firmly cemented in a fine-grained matrix. Lenses of igneous pebble conglomerate occur about seven hundred feet above the base of the formation. These lenses are as thick as seventy feet and are believed to be bars of shore line deposition. Massive, well indurated bands of sandstone occur near the base and at the top of the Blairmore formation.

The formation is 1680 feet thick in the area. Thicknesses of 2300 feet and 2150 feet have been given by MacKay, (1932), in the Blairmore area.

Age and Correlation

Bell (Bell, 1946) placed the age of the Blairmore strata in the Lower Cretaceous on the basis of fossil plant evidence. Within the map-area typical Lower Cretaceous fauna was collected. These specimens include, *Aucella* sp., *Unio hamili*, *Unio douglassi* and *Sphaerium onestae*.

Crowsnest Formation

Name, Distribution and Thickness

G. M. Dawson first recorded the Crowsnest formation in 1881. Descriptions of the volcanics of this formation have been given by W. W. Leach, (1902), C. W. Knight, (1905) and J. D. MacKenzie (1914).

The Crowsnest formation is confined to the Crowsnest Pass area. The southeastward extension of these rocks enters the Carbondale area and has been faulted to the surface in a number of places.

In the Crowsnest Pass the formation has a thickness of 1100 feet. The thickness in the Carbondale area is 500 feet.

Lithology and Age

J. D. MacKenzie (1914) describes the Crowsnest volcanics as consisting of stratified pyroclastic rocks which exhibit several primary types occurring as fragments. These are, in order of abundance, trachytes, blairmorites and latites. These rocks are

often interbedded with tuffaceous maroon, and in some instances, green shales. The volcanics are quite frequently reworked by water, resulting in beds composed mostly of water rounded phenocrysts. Because of the gradational contact at the base of the volcanics and the unconformity at the top of the Crowsnest formation, it is placed in the upper Lower Cretaceous.

Upper Cretaceous

General Statement

Previous reports of the Crowsnest Pass region have used the name Benton to designate the sediments of Colorado age. In this report the divisions of Blackstone, Bighorn and Wapiabi are used in place of Benton. Rocks of Colorado age outcrop in the Alberta foothills from the 49th parallel to the British Columbia-Alberta boundary in the Peace River territory. Moreover, drilling has revealed that Colorado sediments underlie the Alberta plains.

G. S. Malloch (Malloch, 1911) divided the Colorado shales in the Bighorn basin into the Blackstone, Bighorn and Wapiabi and gave them local names which have been carried into other areas.

Blackstone formation

Lithology, Thickness and Age

The Blackstone strata are a series of finely bedded, silty, fissile marine shales. They are in some place nodular and may have a thin layer of siltstone. The basal bed of this formation

in the Carbondale area is a chert pebble conglomerate which is overlain by a sandstone band. The conglomerate and sandstone together are 5.5 feet in thickness (Figure 6).

The formation is, in the Carbondale map-area, 325 feet thick. This is 75 feet less than the thickness given by C. O. Hage (1940) in the Beaver Mines area and only a third of the thickness given by Allan and Carr in the Highwood-Elbow area.

Fossils found in the formation are Exogyra laeviuscula, Inoceramus sp., Watinoceras sp. and Dunveganoceras sp. The presence of this fauna indicates Upper Cenomanian and Lower Turonian age for the formation.

Bighorn Formation

Name, Distribution and Thickness

G. S. Malloch, (1911), first applied this name to a 390 foot series of siliceous shales, shaly sandstones and conglomerate bands occurring in the Bighorn Coal Basin. The formation has the same distribution within the foothills as the Blackstone and Wapiabi shales. Areally the formation is faulted to the surface in many places. However, the formation is only 100 feet thick so it is not bedrock in a large percentage of the map-area.

Lithology and Age

The bottom of the formation is a light grey quartzitic sandstone with a thickness of 30 feet (Figure 7). This is overlain

by shales which much resemble those of the underlying Blackstone but are probably more sandy. The top of the upper band of sandstone is taken as the top of the Bighorn formation. Its thickness is from 12 feet to 20 feet. It consists of dark grey, very fine-grained quartzitic sandstone. Pyrite is scattered throughout the band.

Fossils found in the Bighorn formation are *Exogyra laeviuscula* Roemer, *Prionocyclus wyomingensis* Meek. These fossils are not diagnostic so the formation is placed as Bighorn because of its lithological character and stratigraphic position.

Wapiabi Formation

Name, Distribution and Thickness

Malloch, (1911), gave this name to the shale succession overlying the Bighorn in the Bighorn Coal Basin. It retains much of the same character from the type locality, southeastwards through the foothills to the Carbondale River area.

Within the area it outcrops in several broad bands but in no place is it exposed from the bottom to the top of the formation so true thickness could not be measured. However, the calculated thickness of the formation is 1400 feet which compares with Hage's figure of 1600 feet in the Beaver Mines area.

Lithology and Age

The Wapiabi formation is a series of dark grey marine shales with thin sandstone bands. Near the top of the formation

the sandstone layers become more frequent until it grades into the Allison sandstone.

Marine fossils found in the formation include Inoceramus exogyroides, Scaphites ventricosus, Baculites codyensis, Ostrea (?) sp., and Oxytoma sp. The Scaphites vermiformis and Baculites occur in recognized zones throughout the foothills and so the formation may be correlated with the Wapiabi formation.

Allison Formation

Distribution

The Allison strata occurs in one continuous band from the northwest portion of the map sheet, along the mountain fronts to the southeast corner. Elsewhere within Alberta, strata of Allison age occur both as surface rock and at depth. The most extensive outcrops are those of the southeastern portion of the province.

Thickness and Lithology

The Calculated thickness of the Allison is 4300 feet. Of this thickness the only continuous outcrop in the area measured 878.3 feet.

The strata exposed consist of grey to grey-green sandstone and green shale. The sandstone beds may be friable or well indurated and are commonly cross-bedded. The shales are green in color, sandy and usually of a black nature.

Age and Correlation

Fossils obtained from Allison strata are *Unio minimus* Warren, *Unio* cf. *primaevus*, *Unio* sp., *Viviparus leai* Meek and Hayden, *Corbicula occidentalis* Meek and Hayden, *Corbicula cytheriformis*, *Anodonta* sp., *Ostrea glabra* Meek and Hayden, *Corbicula subtrigonalis* Meek and Hayden, and *Melania wyomingensis* Meek. The first four specimens named are of fresh water origin whereas the latter group is brackish water. These fossils are also found in the Foremost and Oldman formations of the southern plains of Alberta.

Bearpaw Formation

One outcrop of Bearpaw strata was observed. This occurs on the second creek east of the west branch of Castle river and south of Beaver lake. The exposures consisted of dark grey shales, carbonaceous layers and probably a biostrome. This strata appears to be the Bearpaw equivalent but faunal evidence does not definitely identify it. *Corbicula cytheriformis* is possibly of Bearpaw age.

Pleistocene and Recent

Cirques along the fronts of the Flathead and Clarke ranges, abundance of glacial till and erratics and topographic features indicate extensive glaciation in the area. The valleys of Carbondale river, Castle river, Lynx creek and Lost creek have been glaciated. Erratics are found on hills 800 feet above valley level. Most of these hills have rounded contours and resemble

roche moutonnée. Higher hills of the area and some of the mountain spurs were nunataks during the Pleistocene glacial epoch. South of North Kootenay Pass the ice has crossed a col at an elevation of 7100 feet. Warren, (1949), believes that the ice which crossed here was an overflow from the ice sheet which covered British Columbia.

Many terraces of the area are thought to be of glacial origin (Figure 8). During the glacial epoch the valley of Castle river was probably dammed below its junction with the Carbondale. This damming produced a glacial lake in which were deposited sediments to a great depth. When the ice dam melted, the lake was drained and the bottoms remained as a flat. The varying levels of terraces are attributed to the downward and sideways cutting of the Castle and Carbondale rivers.

Gravels in the river beds are probably largely of glacial and recent origin. At several points on the Castle river and at one point on Lost creek a well consolidated recent conglomerate was noted (Figure 9). This conglomerate includes pebbles of Mesozoic and Precambrian origin. It has been cemented by circulation of limy waters.

Competency of Formations in the Carbondale River Area

Definition

Competency is a relative property. A competent formation is strong and can transmit the compressive force much farther

than a weak incompetent formation (Billings, p. 88).

Precambrian and Paleozoics

The Precambrian strata of the Clarke and Flathead ranges, although composed of argillite, and fairly thin bedded limestone, seems to be quite competent as a unit. They have withstood and transmitted the tremendous mountain building forces without abnormal deformation. The preponderance of massive limestone and dolomite in the Paleozoics gives these formations great competency.

Mesozoics

Jurassic

The Fernie formation is composed of fissile marine shales which, when subjected to compressive stresses, will readily fault, fold or act as a slippage zone. They are, therefore, considered to be very incompetent.

Lower Cretaceous

The Kootenay strata includes shale horizons and coal seams. These serve as lubricants for faulting, so often the Kootenay occurs along a fault line. The heavy basal band of the Kootenay formation is, due to its massiveness and well indurated character quite competent.

The basal Blairmore conglomerate is a very competent band. This thick band is well cemented and a massive unit and

therefore has transmitted the faulting forces in many places. Also in the Blairmore formation a massive sandstone at the base and a series of massive sandstone near the top of the formation are able to withstand the compressive forces without great distortion. Shales of the Blairmore formation are sandy and are of the blocky rather than fissile character. The formation, as a unit, is one of the most competent Mesozoic formations of the map-area.

The Crowsnest formation composed of massive rocks of volcanic origin with interbedded tuffaceous shales forms a competent unit, which due to its position adjacent to the Blairmore, has acted with it, in transmitting the compressive forces.

Upper Cretaceous

Two formations of the Upper Cretaceous, the Allison and the Bighorn, are competent. The Bighorn has two massive sandstone bands, which, for so thin a formation, have withstood the mountain building stresses most remarkably. The fissile shales lying above and below the Bighorn have probably absorbed much of the stresses which otherwise would have faulted and folded the formation. The Bighorn sandstones then have frequently faulted to the surface and due to their resistance to weathering, as compared to the surrounding shales, are often expressed topographically as waterfalls and ridges. The sandstones and shales of the Allison formation are very similar to the Blairmore formation and rank with it in competency.

Shales of the Wapiabi and Blackstone formation are very fissile and yield easily to compressive forces. They are a good slippage zone and have acted as such during Rocky Mountain tectonic movements.

CHAPTER IV

REGIONAL ROCKY MOUNTAIN STRUCTURE

General Statement

Sub-parallel fault blocks composed of Paleozoic and Precambrian rocks make up the Rocky Mountain ranges. The faults underlying these blocks are usually westward or southwestward dipping but eastward dipping faults do occur.

Forces from the west and southwest acting in an east and northeast direction, have caused these great thrust blocks to override the plains.

Displacement of the faults is variable. The throw may be as much as 40,000 feet as in the case of the Lewis and Clarke range. Net slip far exceeds this figure and cannot be accurately determined but in northern Montana it has been estimated as being at least twelve miles.

The foothills are usually formed from rocks of Mesozoic age. They are folded and faulted in accordance with the forces exerted upon them during the upheaval of the mountains, so they mirror the trends of the adjacent mountain fronts. The faults in the foothills are usually westward dipping. Both thrust and normal faulting occur.

Transverse faulting is not the rule in either the foothills or the mountain ranges, however, transverse faults are not

uncommon.

Warren (1938) has dated the main uplift of the Rocky at the beginning of Oligocene time. The uplift was followed by an erosional epoch during which time peneplanation took place. During Pliocene time the continent rose and another erosional cycle began. From this last erosional period has resulted our present mountains.

Below is given a more detailed description of the Rocky Mountain structure north and south of the Carbondale River map-area.

XXXXXXXXX

Rocky Mountain Structure of Montana

Structural interpretations of the front ranges of the Rocky Mountains of northern Montana were made by C. R. Clapp (Clapp, 1932). He interprets the major structure along the Montana-Canadian border as a broad synclinorium with faults and folds occurring on both the eastern and western limbs. The eastern limb is narrower, steeper and more intensely folded than the western limb. The western limb is broken by four or five longitudinal faults. (Figure 11, Cross section 1).

Faults in the western limb bow out to the southwest and dip to the northeast at angles of 60 to 80 degrees; easterly faults bow out to the northeast and dip southwest at angles of 55 to 75 degrees. Therefore, two sets of faults bound on the east and west great downward tapering wedges. The throw of the faults

is 10,000 to 30,000 feet. The western faults have been named from the mountain ranges which they uplift. Of the eastern faults only the Lewis and Clarke fault, which follows the Lewis and Clarke range has been named. This fault with a throw of 40,000 feet brings southwestward dipping Beltian rocks over southwestward dipping Palaeozoic rocks. East of the Lewis thrust smaller thrust faults occur in the Paleozoic and Mesozoic strata.

The Lewis and Clarke thrust fault in the Montana area has 28 degrees west strike and an average dip of 30 degrees. It has a maximum vertical displacement of 40,000 feet and a maximum net slip of 12 miles. In some places the fault consists of a series of parallel faults; in others it is one simple fracture with little disturbance of the rocks on either side. At the international boundary the fault has a dip of about 7 degrees and the fault surface either has been warped or was uneven when formed. Chief and Divide mountains are "klippes" composed of Belt series rocks lying on Mesozoic strata.

South of Glacier Park the Lewis and Clarke fault steepens to 30 degrees. Two hundred and ten miles south of the international boundary the fault has a northeast trend with a dip of 40 degrees to the northwest and is known as the Lombard fault.

Clapp attributes the deformation, along the main thrust lines, to forces which acted from the southwest in a northeasterly direction.

Structure of the Flathead valley

The Flathead valley is one of the longitudinal troughs or trenches of the Rocky Mountain system. Because of oil seepages in the Precambrian rocks of this valley and the adjacent Clarke range its structural features have been studied in some detail. No definite interpretation of the Structure has been given but three explanations have been postulated. Each of these is inconclusive, in that, much of the evidence is concealed by Tertiary and Recent deposits.

Daly (1912), Willis (1902) and MacKenzie (1922) explain the Flathead structure by the fault graben theory. This would necessitate, according to these authors, a normal tension fault along the west side of the Clarke range. Drilling has revealed that this fault, commonly termed the Flathead fault, does not dip westward but is an eastward dipping fault. It is noted that the authors here in describing a graben use the keystone theory. Holmes in his text on physical geology points out that fault graben could be due to compressional forces which cause a downward widening wedge to be forced down. The fault graben theory for the Flathead might better be explained in this manner.

Daly (1912) thought it possible that the whole Flathead valley is a window. This would require a very low angle and possibly warped Lewis thrust fault. This explanation does not meet with mechanical difficulties. Precambrian strata on the west side

of the valley lie upon rocks of Devono-Carboniferous age. On the east side the Precambrian rocks overlie the Mesozoics. It is possible then that at one time a great mass of Precambrian rocks overrode the younger Paleozoic and Mesozoic formations. This idea is quite acceptable and may be correct but this cannot be definitely proven because the Flathead fault is not exposed.

Private investigations of the Flathead valley adjacent to and south of North Kootenay Pass have led to evidence which shows that the movement of the Precambrian rocks with respect to the underlying formations has been eastward. This would seem to indicate that the window theory is the logical explanation.

T. A. Link (1932), has suggested a "ramp" or inverted wedge theory. A ramp is interpreted as being a keystone wedge such as would result from a pair of over and underthrust faults. In the case of the Flathead valley, the west is the overthrust side and the east the underthrust side. Link's suggested interpretation is shown in Figure 11, Cross section 2. It is noted that the underthrust fault dies out at depth and does not preclude the possibility of a low angle Lewis overthrust fault.

Pierre de Bethune (1936) has studied the structure of the Flathead basin in the vicinity of Flathead townsite and North Kootenay Pass. His cross section, which is taken just north of North Kootenay Pass is shown in Figure 11, Cross section 3. Bethune terminates the Flathead fault in the area of the townsite. He

suggests that it merges with one of the faults continuing northward. The difficulty arises here in that the northern faults have a westward dip while there is fairly conclusive evidence that the Flathead fault dips eastward. One of the northern faults cuts directly through the Paleozoics of the Flathead range and merges with the main overthrust fault a few miles north of North Kootenay Pass. Bethune favors the window theory for an explanation of the Flathead trough.

Structure of Crowsnest Pass area

The regional structure of the Crowsnest Pass area is comparatively simple (Figure 11, Cross section 4). MacKay (1932) has shown that the Paleozoics of the Crowsnest range dip under the Mesozoic sediments of Fernie basin. On the east side of Crowsnest range the Paleozic rocks have faulted over the Mesozoics at a low angle. Warren (Warren, 1933) estimates that because of the position and altitude of the fault plain underlying Crowsnest Lake mountain, a klippe, that the angle of thrust cannot exceed 15 degrees. East of Crowsnest range two other Paleozoic blocks have been faulted up, namely, the Blairmore Range and Livingstone Range the latter being actually two ranges brought up en echelon. The Livingstone Range is bounded by a thrust fault which carries on into the Mesozoic sediments to the south of the range. Several faults and folds occur in the Mesozoic strata, the most important feature of these being the faults that have brought Kootenay coal seams to or near the

surface. West of the Crowsnest range the Mesozoics are folded into a broad basin which is bounded on the west by the complex anticlinal structure of Erickson ridge.

GEOLOGICAL STRUCTURE WITHIN CARBONDALE RIVER AREA

Introductory Statement

To the west and southwest of the Carbondale River map-area the Paleozoics and Precambrian are thrust over Mesozoic strata. The latter have been faulted and folded due to the forces exerted upon them during the overthrusting of the Paleozoic-Precambrian fault block. The folded and faulted blocks, since their upheaval, have been eroded and glaciated. The resultant ridges and valleys have, in the northern portion of the area, a north twenty degrees west trend; those in the southern parts have a north 55 degrees west trend. Most of the faults are of the longitudinal type but transverse faults occur along the upper Carbondale river and in the locality of Byron hill. Minor faulting is very abundant throughout the area and in the less competent shale horizons and coal seams much of the movement has been accomplished by slippage.

Structure of the Upper Carbondale River area

This portion of the map-area has been observed by many expeditions from Palliser's time to the present. Hume on his journey through North Kootenay Pass noted and made reference to the anticlinal nature of the Lewis thrust at this point (Hume, 1932). Other

observers did not make any particular reference to the structure of the rocks.

Kootenay strata underlie the overthrust in this locality. The Kootenay is faulted over the Blairmore and the Blairmore is faulted over the Wapiabi. The Kootenay and Blairmore strata are intensely faulted and minor folds occur in them. The average dip of the bands is 45 degrees but dips as low as 7 degrees and as great as 68 degrees were recorded. The Kootenay is a slice brought up over the Blairmore band on a low angle thrust fault which at depth is believed to join with the main overthrust. The fault underlying the Blairmore is an imbricate and longitudinal fault. The greater part of the slippage has been in the plane or nearly in the plane of the dip of the strata.

Lying east of this imbricate fault is a faulted and eroded anticline. In cross section C-D this anticline begins with the most westerly band of Wapiabi formation. Eastward the Wapiabi band is succeeded by Bighorn (at depth), Blackstone, Crowsnest Volcanics, Blairmore, Crowsnest Volcanics, Blackstone, Bighorn and Wapiabi which is faulted over the younger Allison strata. Faulting occurs on both limbs of the anticline and in the centre. On the west limb the Wapiabi formation is faulted, the apparent displacement being greater to the north where the Wapiabi contacts the Crowsnest formation rather than the Bighorn. On the eastern limb the Crowsnest formation is faulted over the Wapiabi shales. The fault in the

central part of the anticline may have quite a large displacement. A well indurated Blairmore sandstone which overlies forty feet of the basal Blairmore conglomerate is present on the first ridge west of Prospect hill. It is lying above the conglomerate, as is the normal sequence, but the usual shale parting between the sandstone and conglomerate is missing. This and the slickensiding observed denotes faulting. If this faulting were of a minor displacement, Kootenay strata would appear in the Carbondale river, thirteen hundred feet lower than the ridge. Kootenay strata was not recognized in this sequence, in the valley of the Carbondale, so the fault must have a displacement of at least thirteen hundred feet. The faults on the east and west limbs do not have a displacement of more than four hundred feet.

It is not definitely known that the anticlinal structure ends with the faulting of the Wapiabi over the Allison. It is felt rather that east limb of the anticline includes some of the Allison formation. This would then account for the abnormal calculated thickness of 6000 feet for the Allison formation.

Along the Upper Carbondale a transverse fault has been drawn. This fault was not actually observed and probably does not exist as a fault. It might better be referred to as a fault zone. It is impossible to reconcile the north 80 degrees west strike of the strata north of the Carbondale river without faulting. Evidence of this faulting is present in many outcrops one of which is shown

in Figure 10. The photograph shows Blairmore strata faulted over Blairmore strata. The incompetent shales and coal of the Blairmore and Kootenay formation have absorbed much of the faulting and have therefore reduced the apparent displacement. This faulted zone will be discussed further in the description of the overthrust fault.

South of the river three peculiarities, in the strata underlying the overthrust, are noted. The nose of Precambrian rock, jutting out between Macdonald creek and Carbondale river, faults out the Kootenay strata leaving the Blairmore formation underlying the overthrust. Secondly, on the northwest side of this ridge a narrow slice of Fernie is brought up with the Kootenay strata. This slice is the finely banded sandstone of the upper Fernie so it is not displaced a great deal further than the Kootenay underlying it. Lastly, on the north slope of Mount McCarty and underlying it an additional band of Blairmore and Kootenay has been exposed. The strata underlying the thrust in this latter locality is a slice of Kootenay strata. This is faulted over Blairmore which in turn overlies Kootenay. This latter contact is not exposed so it is assumed to be normal. The next Kootenay band overlying the Blairmore is faulted and overturned. This is probably a portion of the east limb of the anticline described above. The Kootenay coal measures overlie the basal Blairmore conglomerate which is at this point fifty feet thick.

The band of Blairmore underlying the conglomerate is, of course, overturned. It is faulted over the underlying volcanics

which in turn is faulted over the Blackstone.

Structure at the Headwaters of Lynx and Lost Creeks

The structure on the north branch of Lost creek and the west branches of Lynx creek is a continuation of the Carbondale structure. Here Kootenay strata underlies the overthrust Precambrian rocks and is faulted over the Blairmore (Figure 12). However, this band of Blairmore is not the one underlying the overthrust in the Carbondale district, but is the east arm of the anticline which has plunged northward from Prospect hill and partially disappeared under the main overthrust fault.

A slice composed of Upper Fernie and basal Kootenay strata has been brought along the thrust fault and is exposed on the ridge lying between Lynx and Lost creeks.

The Allison strata is included in the east limb of the anticline, then faulted along the axis of the adjoining syncline and folded into another broad anticline and syncline. This interpretation is based on both topographic expression of the formation and the dips obtained. A northwestward trending ridge is located in the northern portion of section 18, township 6, range 4. Eastward dips occur along the top and east side of this ridge which indicates the trough shown in section A-B.

Structure of the Mesozoics south of Carbondale river and under the main overthrust

It has been noted that the strike of the main overthrust fault changes south of the Carbondale river. This change of strike results in a gradual advance of the thrust fault over the Kootenay to Wapiabi sequence of strata until finally at the south fork of Castle river the thrust fault overlies Allison strata.

On upper Gardiner creek a thin band of Kootenay underlies the main thrust. The Kootenay strata is underlain by strata of the Blairmore, Crowsnest Volcanics, Blackstone, Bighorn and Wapiabi. This is the east arm of the Prospect Hill anticline. Here it is not plunging out as north of the Carbondale, but is being faulted out by the overthrusting Precambrian rocks.

Southeastward to O'Hagen creek the Blackstone is faulted out by the more competent volcanics being thrust over it and the Precambrian overrides the Kootenay wedge. Finally between the two branches of the Castle river the Precambrian lies directly on the Allison. This condition persists eastward throughout the remainder of the map-area.

Willoughby Ridge and Cherry Hill

Willoughby Ridge enters the map-area in section 27, township 6, range 4. Formations of the ridge are from west to east Crowsnest Volcanics, Blairmore and Kootenay. The Kootenay formation is faulted over the Wapiabi. This ridge continues in the map-area

with a general trend of north 25 degrees west until it reaches Lynx creek south of which it terminates in Cherry hill. The ridge throughout its length has a double crest, one formed by the Crowsnest Volcanics on the west and the second formed by the basal Blairmore and Kootenay sandstone. Forces exerted upon the ridge have caused the strata to be squeezed and pushed so that proceeding south the distance between crests narrows and the Kootenay strata on the eastern side is almost completely faulted out.

Cherry hill offers a complicated structural condition. North of Cherry hill the bands of strata are, from west to east, Crowsnest Volcanics, Blairmore, Kootenay, Blairmore, Crowsnest Volcanics, Wapiabi, Bighorn, Blackstone, Crowsnest Volcanics, Blairmore and Wapiabi. Relations of the formations and faulting is shown in the accompanying map (Figure 13). These formations are exposed in almost continuous outcrop along Lynx creek. However, on the south side from west to east along Carbondale river, which too offers continuous outcrop, the succession of bands from west to east is Blairmore Wapiabi, Bighorn Blackstone, Bighorn and Wapiabi. The upper portion of Cherry hill is a broad block of Blairmore strata which is anticlinal on the west and synclinal on the east. Both of these structures have a 15 degree plunge southward.

Cross section B-C shows that anticlinal synclinal feature observed on the surface of Cherry hill also occurs at depth. The two outcrops of Bighorn strata on Carbondale river indicate that

this formation too is anticlinal. It is therefore concluded that this local folding of the strata has carried to some depth. The stratal bands north of Cherry hill then have been folded and have plunged out beneath Cherry hill.

Maverick Hill and Maverick Hill Fault

Maverick hill lies on the east side of Turtle Mountain anticline and is a portion of the east arm of that structure. Its structure is of interest not only from a scientific view point but also from the economic because the Kootenay band which is mined at Adanac in the Blairmore area continues southward into Maverick hill.

The major part of the disturbance in Maverick hill has centered around a north-south striking fault with an easterly dip. It was not possible to see exactly where this fault began on the north portion of the hill but a mile south of the northern boundary of the map area the fault is very pronounced. When first observed the fault has an eastward dip and centres about strata at the Kootenay-Blairmore contact. As the fault continues southward the dip becomes vertical and then dips slightly westward.

The strata on the west side of Maverick hill and about half way down is eastward dipping and the Kootenay strike lies in a normal manner on the Fernie. About two thirds of the way up the hill on the same side the faulting begins and stratal dips are

much steeper but still eastward. On top of the hill the strata is badly faulted and folded but in general it is upright. This does not apply to the broad band of sandstone which is faulted into a horizontal attitude along the southern summit of the hill. Down the east side of the hill the dip becomes westward and the Blairmore strata is overturned. From north to south then on Maverick hill there is a change from normal lying strata to upright strata, to overturned strata. Figure 14 shows the beginning of the faulting and a portion of the basal Blairmore strata, with an attitude of north 9 degrees west, 68 degrees east.

Coal seams and shale horizons have here, as in many cases throughout the area, served as a lubricant for faulting. Outcrop of coal on the surface is only in small showings, the bulk of the seams having been faulted out by more competent strata. It is thought that by careful plotting of the attitude of horizons adjacent to the coal and correlating these with horizons at Adanac Mine the positions of coal seams at depth could be accurately determined. For instance, it was noted that the unconformity which is described in the discussion on Blairmore strata lies about three hundred feet above the Blairmore-Kootenay contact above Adanac Mine. On the southeastern portion of Maverick hill this unconformity is overturned and lies 300 feet below the main fault line.

Strata of the hill have been subjected to more than one compressional force. A heavy basal band of Blairmore sandstone

observed on the south end has been pushed from the south as well as the east. Looking north from the valley of the Carbondale river this band which is thirty feet thick has been folded and faulted into the shape of an S.

Carbondale Hill Structure

Carbondale hill lies south of Maverick hill. It includes strata from the volcanic band lying east of George and Lynx creeks to the Kootenay of Maverick hill.

The southwest peak which is also the highest point of Carbondale hill is formed by a ridge composed of Crowsnest Volcanics. This ridge is a continuation of the volcanics lying east of George creek and the strike having changed from north 25 degrees west to north 50 degrees west. These volcanics are a part of the west arm of the Turtle Mountain anticline. East of the volcanic ridge the dip of the Blairmore strata changes from west to east. This is the southernmost expression of Turtle Mountain anticline.

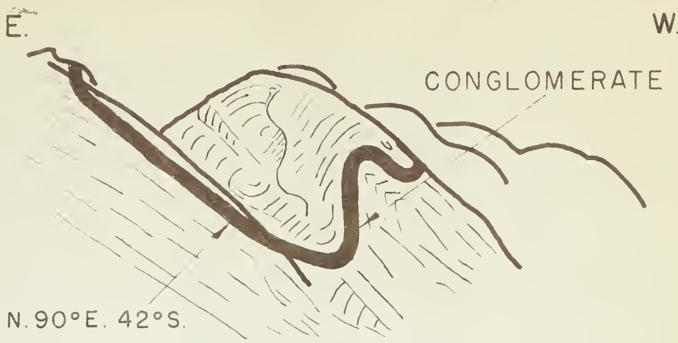
The anticlinal attitude of the strata may be observed from Carbondale river to the crown of the hill. In the heart of the anticline the Jurassic strata occurs with both east and west dips in accordance with the limb it is on. This is overlain by Kootenay which is overlain by Blairmore.

As in the case of Maverick hill, the strata of the east arm of the anticline on Carbondale hill is much distorted. From

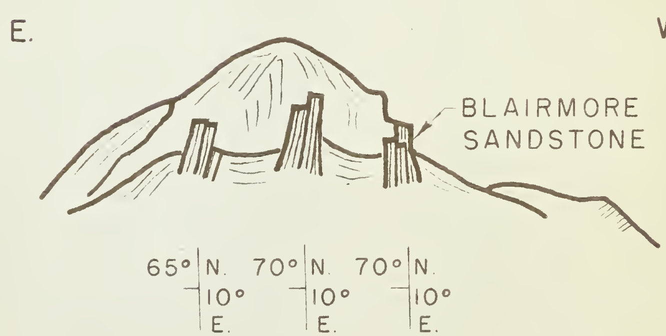
the point where the eastward dips begins, to the eastern side of the hill, the Blairmore is folded and faulted, the axes of the folds and the trends of the faults being in a north 10 degrees west direction. This folding is illustrated by the sketches shown below. The first sketch shows basal conglomerate of the Blairmore formation folded along the east limb of the anticline. The second sketch gives the attitude of Blairmore ridges along the north crest of Carbondale hill and also on the east arm of the anticline.

It would appear from the above attitudes that the formational forces on Carbondale hill were from the west acting east. However, there is along the north side and adjacent to the Carbondale river a fault with a southwest trend. The fault line may be observed along the river bed. Movement along this fault line has been north and eastward and has brought the Blairmore and Kootenay strata of Carbondale hill over the north to south folds of Blairmore, Crowsnest Volcanics, Bighorn and Blackstone formations north of the Carbondale river. This may best be observed in the north half of section 9, township 6, range 3. Here the Kootenay strata has a general east-west strike and the underlying formations over which it is thrust strike in a general north-south direction.

Evidence of this northward component of thrusting is seen on the southern flank of Carbondale hill. Here both transverse and longitudinal faulting of the anticline occurs. This transverse faulting and the transverse faulting east of this is the result of



SKETCH 1.



SKETCH 2.

a thrust component acting in a N-S direction. The transverse faulting may continue northward through Carbondale hill and across the Carbondale river but present evidence does not warrant extending it that far.

Carbondale hill is then the southward expression of the plunging Turtle Mountain anticline with the east limb faulted and folded. Also in its strata, a northward component of force has expressed itself by both transverse faulting and thrust faulting the latter having a fault plane with an east-west strike.

Anticlinal Structure of Ginger Hill

Ginger hill is located north of the junction of the Carbondale and Castle rivers. It is structurally an anticline with a southeastward plunge. The anticlinal condition is not so apparent on the top of the hill because erosion has removed much of the east arm and vegetation has covered the outcrop. Too, a fault occurs along the east arm of the anticline. This fault brings the igneous pebble conglomerate which is seven hundred feet above the base of the Blairmore to the surface. However, the rock exposed on the hill-top is two hundred feet higher stratigraphically than the conglomerate so the displacement has not been very great. The fault varies in attitude from slightly eastward dipping to vertical and strikes in the same direction as the anticline.

The southward extension of the anticline is exposed both

on the Carbondale river and Castle river. Both of these streams are antecedent to the anticline and therefore expose a cross section of it. This cross section is best observed on the south bank of Castle river just above its junction with the Carbondale. Here the Blairmore forms the centre of the anticline (Figure 15). Then progressing up or down the stream the strata exposed is Crowsnest Volcanics, Blackstone and Bighorn.

The fault in the east limb is transverse to the strata of that limb. On the top of Cherry hill it is exposed in Blairmore strata, on the Carbondale river it is seen in the Crowsnest Volcanics and along the Castle river it has faulted into Bighorn and Wapiabi strata.

It is not possible to identify horizons accurately enough or to get a true dip to determine the exact plunge of this anticline but by estimating the stratigraphic position of the Blairmore rocks exposed on Ginger hill it is calculated that the plunge is 5 degrees.

Backus Mountain Thrust

The name Backus Mountain Thrust is given to denote a main thrust line of Mesozoic strata over Mesozoic strata. This thrust begins in the vicinity of Carbondale hill and has been described there as Kootenay strata thrust over north and south folds. At the east end of Carbondale hill the fault trace changes direction 90 degrees. From here the direction of the trace is north 45 degrees

west. The dip of the fault plane is 25 degrees.

This fault throughout its course in the map-area and in the Beaver Mines map-area to the east is different from the usual type of fault for the area in that it does not follow the regional trend. It is a thrust fault and not a transverse fault because it follows along the front of the Blairmore and rides over the areal structures and strata rather than faulting through them.

The direction of the force causing this thrust must have been in a different direction from that which produced the north-south folds of the area. This then is another expression of the northward acting component of force.

In the eastern portion of the map-area and both north and south of the Backus Mountain thrust, slice faulting occurs. The slicing is caused by the northward component. In mapping the slices an attempt has been made to show how they arrived in their present position. The faults involved in the slicing are not exposed.

Turtle Mountain Anticline

The southern extension of the Turtle Mountain structure which here is described as the Turtle Mountain anticline enters the Carbondale map-area at section 24, township 6, range 3. The western limb of the anticline is not exposed but that of the eastern limb is. The Paleozoic strata of the eastern limb as it enters the map-area strikes north 5 degrees east, and dips 60 degrees east.

The anticline is plunging south 20 degrees east at an angle of 6 degrees. Paleozoic rocks disappear under Fernie strata in the middle of the east boundary of section 24, township 6, range 3. From here, south to O'Hagen creek, Fernie strata occupy the centre of the anticline, then Kootenay and finally Blairmore.

Both the west and east arm of the anticline are faulted and folded. Faulting on the west arm is imbricate. The faulting of this arm may be said to extend as far as Lynx creek. However, adjacent to the axis the main fault is one which brings the Kootenay strata over Blairmore strata, the Kootenay coal having again acted as the lubricant for faulting. This fault extends south to the Carbondale river. Faulting of the east arm has been dealt with in the discussion of Maverick hill.

The upheaval of this anticline of Paleozoics is considered to be contemporaneous with the Rocky Mountain uplift.

The Main Thrust Fault

Areal Description

The main thrust fault of the Precambrian and Paleozoic rocks over rocks of Mesozoic age lies to the south, southwest and west of the map-area. Within the area the trend of surface trace of the fault changes from a north-south direction in the north to a southeasterly direction in the south. Glacial material and talus cover the point of contact over most of the area but it was observed

on the ridges at the headwaters of Lynx creek, section 13, township 6, range 5, west of the fifth meridian; on the southeast slope of Kootenay North; and on the northern slope of Table mountain, section 2, township 5, range 3, west of the fifth meridian. At the first outcrop mentioned, on upper Lynx creek, the Precambrian limestones are thrust over the coal bearing Kootenay strata. Much of the movement has been absorbed by the Kootenay coal seams so very little gouge appears. The Kootenay strata has an attitude of north 20 degrees west, fifty degrees west. No accurate attitude could be obtained for the Precambrian strata because of its being intensely folded and faulted. The exposure of the contact at Kootenay North revealed Precambrian overlying Kootenay sandstone but in this instance there is six inches of black gouge. The gouge is very fine-grained and contains pulverized carbonaceous matter. The attitude of the fault plane at this and the first location is north 15 degrees west 20 degrees west. The exposure on Table mountain shows Precambrian strata overlying that of the Belly River formation. The Precambrian is faulted and folded very intensely (Figure 16). The gouge is eleven inches thick and lies between a black argillite on top and green Belly River sandstone below (Figure 17). The fault plane at this point strikes north 85 degrees west and dips 21 degrees south.

Strata above and below the thrust was observed at a number of places where the actual contact is not exposed. However, it

was possible from these outcrops and the exposed contact to determine the strike and dip of the fault.

The dip of the fault plane within the Carbondale map-area is 20 degrees. The strike varies. The measured strike on Table mountain is north 85 degrees west, on the mountain front between the branches of Castle river it is north 70 degrees west; in Gardiner Creek valley it is north 80 degrees west and along the north of Mount McCarty it strikes north 80 degrees west. On North Kootenay the strike has changed to north 20 degrees west which is the attitude that persists to the northern boundary of the map-area.

It was noted as Hume (1932) described that along the major portion of the thrust Kootenay strata has been associated with the thrusting. Hume points out that not only are coal beds less competent but they seem to act as a lubricant. Coal seams underlying the overthrust were noted on upper Lynx creek (Figure 12), Kootenay North, the upper Carbondale river and Mount McCarty. Hume too notes that slices of Paleozoic rocks are brought up along the thrust on Mount McCarty. These slices were not observed or if observed were not recognized as such.

The Lewis Thrust

The Lewis thrust has been studied in some detail in Montana. Here the thrust has a northwest trend and dips southwest at 3 to 7 3/4 degrees.(Willis, 1902). Willis also noted that the fault plane was warped. Marland Billings (1938) does not agree

with Willis's interpretation of the Lewis thrust as an "erosion thrust". He says that the absence of overridden talus and gravels along the thrust plane indicates that the Lewis overthrust is not an erosion thrust but is a subsurface fault. Also Billings agrees with Daly in a Laramide age for the thrusting. Hume (1932) in commenting on the structure in North Kootenay Pass area notes that the attitude of the fault changes from south 80 degrees west with a southerly dip of 14 degrees to an attitude on Kootenay North of north 20 degrees west and dipping 20 degrees west. He suggests that this may be due to warping of the fault plane subsequent to faulting. The main overthrust fault in the Crowsnest Pass has been referred to as the Lewis thrust.

In the foregoing pages on the discussion of structure it was noted in several instances that the forces acting upon the strata were not always in the same direction. Attention is drawn to the following cases. The regional trend of the ridges changes within the area to a more northerly direction, the difference of strike being as much as 25 to 30 degrees. The strata on the south end of Maverick hill has been subjected to a north-south stress which has folded into an S-shape. Also the Backus Mountain thrust fault is thrust in such a direction that a northward component of thrust is necessary to explain it. Moreover, this thrust has overthrust strata and structure with a north-south strike. In the Carbondale River valley north of Mount McCarty the faulting becomes more intense than

elsewhere observed and the slickensiding observed on the fault block denotes movement to the northeast.

However, north of the general line of the Carbondale river this northward component of force seems to disappear entirely and the only force acting was acting from the west or slightly south of west. It would appear then that a definite change of direction of force occurs in North Kootenay Pass area.

We have noted in discussion of Clapp's work in Montana (Clapp, 1932) that the forces causing uplift were acting from the southwest. Also when the direction of force changes in the south the main overthrust fault name is changed from Lewis to Lombard.

It would appear then that the Lewis thrust fault begins in the south where faulting is caused by a southwesterly to north-easterly force and it is here suggested that the use of the name Lewis should be discontinued where the northwesterly force discontinues, that is, in the vicinity of, or at North Kootenay Pass.

It is not suggested that the actual fault has discontinued but it has been noted that the discontinuance is in a fault zone. Change of direction of force has been brought about both by faulting and warping of the strata. Probably no one major fault exists but closer investigation may reveal a fault zone through the Clarke range to the Flathead valley. This idea is substantiated by Bethune's description of an east-west striking, southward dipping fault zone at Flathead townsite.

It is conceivable that the Lewis thrust is the result of two forces which are not contemporaneous. It is noted that the north-south trending structure is overridden by the Backus Mountain thrust both in the vicinity of Backus Mountain and also north of Carbondale hill. It is obvious then that the northward thrusting was of a later date than that of the eastward thrusting and so the Lewis thrust as here defined is in part a younger thrust than the thrust lying north of North Kootenay Pass.

CHAPTER V

SUMMARY AND CONCLUSIONS

The Carbondale River area lies in the southwestern part of Alberta, seven miles south of Blairmore and fifteen miles west of Pincher Creek. The area is accessible by automobile from Bellevue, Burmis or Pincher Creek.

The area includes both mountainous and foothill terrain. The Clarke and Flathead ranges lie to the southwest and west of the map-area. The Castle river and its tributary the Carbondale are the main drainage arteries. Streams draining into these rivers are of both the subsequent and antecedent type.

Settlement within the area is very sparse. Most of the people within the area are employed in the lumbering industry. Forest growth is very abundant in the western portion of the map-area.

Rocks of the area range in age from the Precambrian to the Recent. Precambrian rocks form the Clarke range, and Paleozoic and Precambrian rocks form the Flathead range. The foothills are composed of Mesozoic rocks of Jurassic and Cretaceous age, and Tertiary rocks of Pleistocene and Recent age. The Mesozoic and Tertiary rocks are, with the exception of the Crowsnest formation, shales and sandstones of marine, brackish and fresh water origin. The Crowsnest formation is composed of igneous extrusives and pyroclastics. Pleistocene rocks are both of glacial and recent

origin. The glaciers deposited till and erratics as they moved down from the large mountain cirques. The rivers have, since glacial times, deposited gravel, sand and silt along their courses.

Structurally the area might be described as containing the convergence of three phases of regional structure. Due south of the map-area lies the Waterton region. Except for local warping, rocks and faults of the Waterton area dip to the southwest and strike northwest. The Lewis thrust is low-angled and probably warped. On the north of the Carbondale River area, in the Crowsnest Pass region, the strata dips westward and strikes a few degrees west of north. The main overthrust fault in Crowsnest region is steeper than it is in the Waterton area. To the west of the map-area lies the Flathead valley and its complex structure. It is known of the Flathead that it is bounded on the west by a westward dipping fault, on the east by by an eastward dipping fault and on the north in the vicinity of the locality of Flathead townsite by a fault zone some elements of which are south and southwestward dipping.

The structure of the Carbondale river expresses all three of these structural conditions. The strata of the northern portion strike and dip in general conformity with those of the Crowsnest region; that of the southern portion follows the general trend of the northern portion of the Waterton areal structure. The east-west fault zone in the Flathead townsite vicinity is probably the same fault zone that extends along the upper Carbondale river. Too,

the synclinal structure of the Clarke range does not extend further than North Kootenay Pass.

The foothill structure of the map-area expresses two definite directions of the force which caused the faulting and folding. The force acting from almost due west was the first force which folded and faulted the strata. This was followed by a north-eastward acting force which caused the north-south structure to be partially overridden. The most northerly expression of this north-ward component is along the upper Carbondale river.

Because the Lewis thrust is attributed to a northeastward acting force in the Montana region and is also partially the result of a northeastward force in the Carbondale area, it is suggested that the name Lewis be applied to the main thrust fault only as far northward as North Kootenay Pass, north of which the results of the northeastward component of force are not observed.

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FIGURE 1

Looking north from North Kootenay Pass along the Flathead range. Precambrian strata forms the slopes on the right and Paleozoics the precipitous slopes on the left. Precambrian-Paleozoic contact is in saddle in division between light and dark in middle right.

FIGURE 2

Adanac strip mine as viewed from the south end.

FIGURE 3

Paleozoic-Mesozoic contact. Fernie rocks disconformably overlie the Paleozoic strata.

FIGURE 4

Vertical Kootenay strata on Lynx Creek.


Jf

FIGURE 5

Kootenay coal lying unconformably over basal Kootenay sandstone.

FIGURE 6

Contact between Crowsnest formation and Blackstone formation. Sandstone and conglomerate of basal Blackstone overlying ash beds.

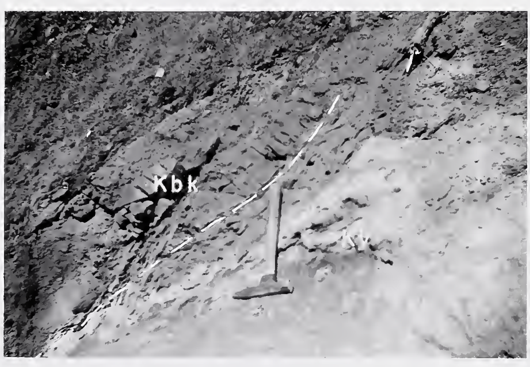

Kbk
Kv

FIGURE 7

Bighorn sandstone forms waterfall on Lynx Creek.

FIGURE 8

Terraces at the junction of Castle and Carbondale rivers.
Carbondale hill is right background.

FIGURE 9

Pleistocene and Recent gravels along Castle river. Recent conglomerate along right side of stream in right middle.

FIGURE 10

Faulting of Blairmore strata over Blairmore strata.

FIGURE 12

Coal seam lying under main overthrust. Location: Headwaters of Lynx creek.

FIGURE 13

Crowsnest volcanics faulted over Wapiabi shale.

FIGURE 14

Faulted strata at Blairmore-Kootenay contact.

FIGURE 15

Anticline on Castle river.

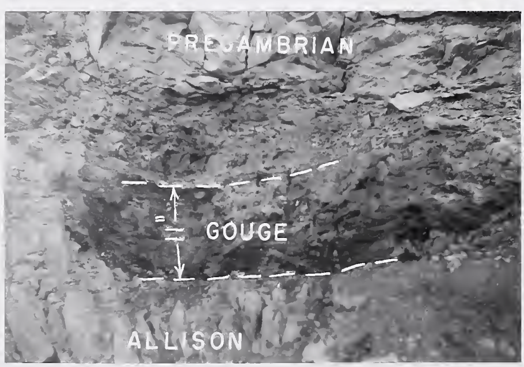
Blairmore strata in centre of anticline.

FIGURE 16

Folded and faulted Precambrian strata lying just above main overthrust.

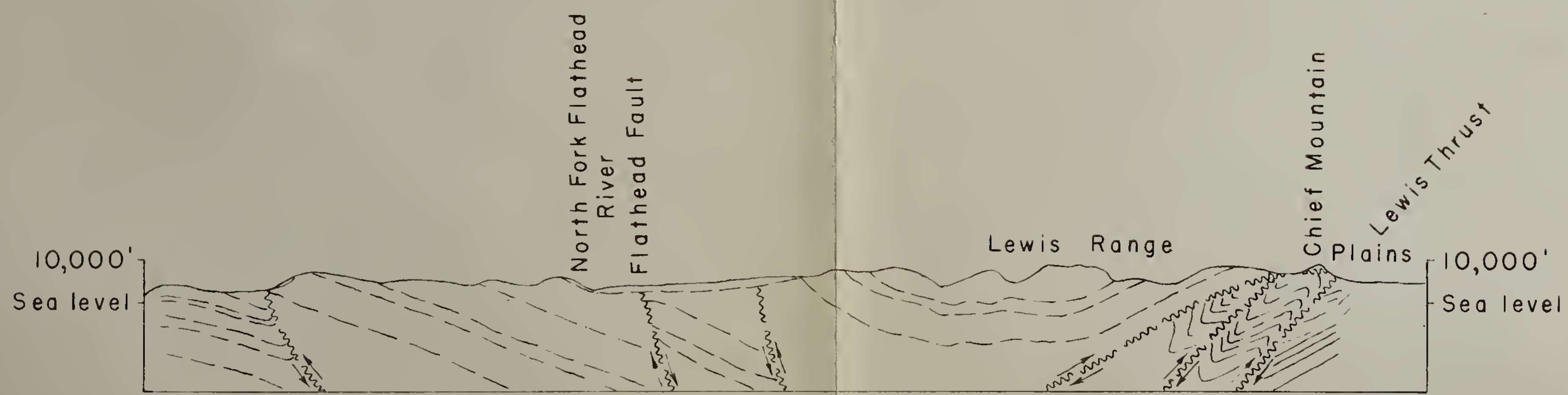
FIGURE 17

Fault contact on north slope of Table mountain. Precambrian thrust over Allison.


PRECAMBRIAN
GOUGE
ALLISON

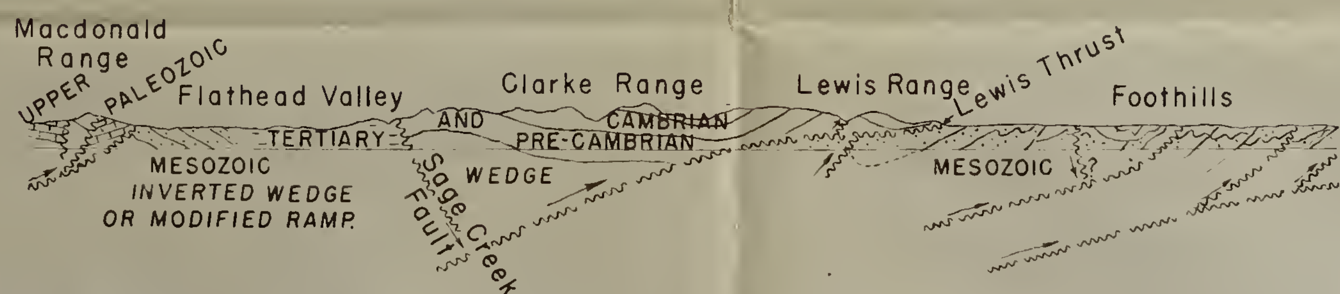
—PLATE II—

NUMBER 1



STRUCTURE SECTION ACROSS FRONT RANGES OF ROCKY MOUNTAINS IMMEDIATELY SOUTH OF INTERNATIONAL BOUNDARY. (C.H.CLAPP, 1932.)

NUMBER 2



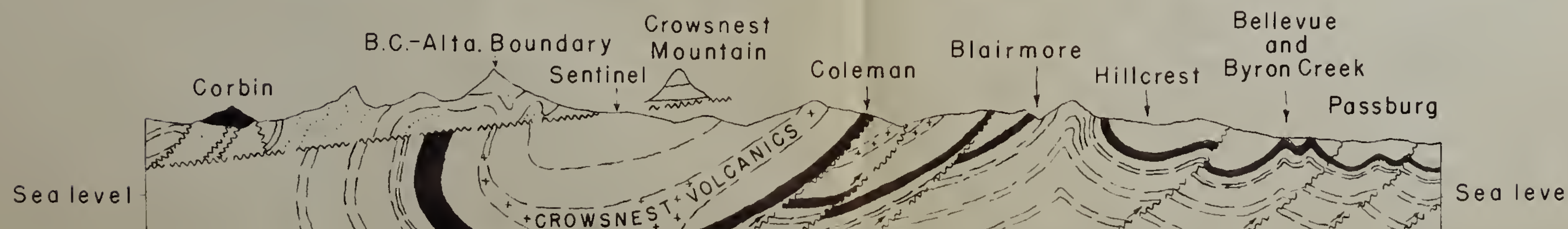
STRUCTURE SECTION IN FLATHEAD VALLEY IS INTERPRETED AS AN "INVERTED WEDGE" OR MODIFIED "RAMP" AND LEWIS AND CLARKE RANGES AS BOUNDED BY UNDERTHRUST ON WEST AND LEWIS OVERTHRUST ON EAST SIDE. (DATA FROM R.A.DALY, J.D.MACKENZIE, J.S.STEWART, D.B.DOWLING AND T. LINK.)

NUMBER 3

NUMBER 3

STRUCTURE SECTION ACROSS FRONT RANGES AND FLATHEAD VALLEY. IMMEDIATELY NORTH OF NORTH KOOTENAY PASS.

NUMBER 4



STRUCTURE SECTION FROM CORBIN TO BURMIS.

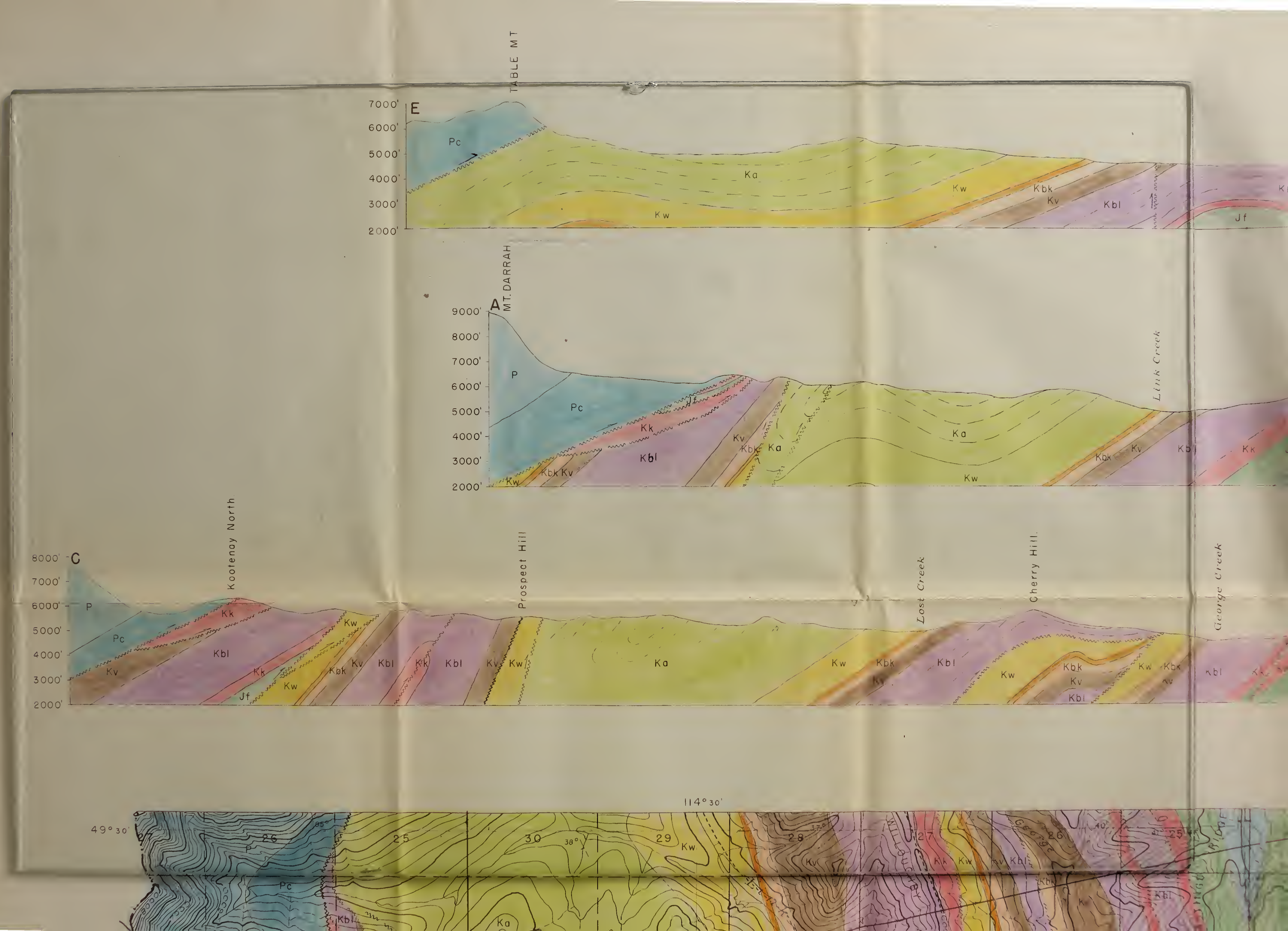


TABLE MT
E
7000'
6000'
5000'
4000'
3000'
2000'
Pc
Ka
Kw
Kbk
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Jf
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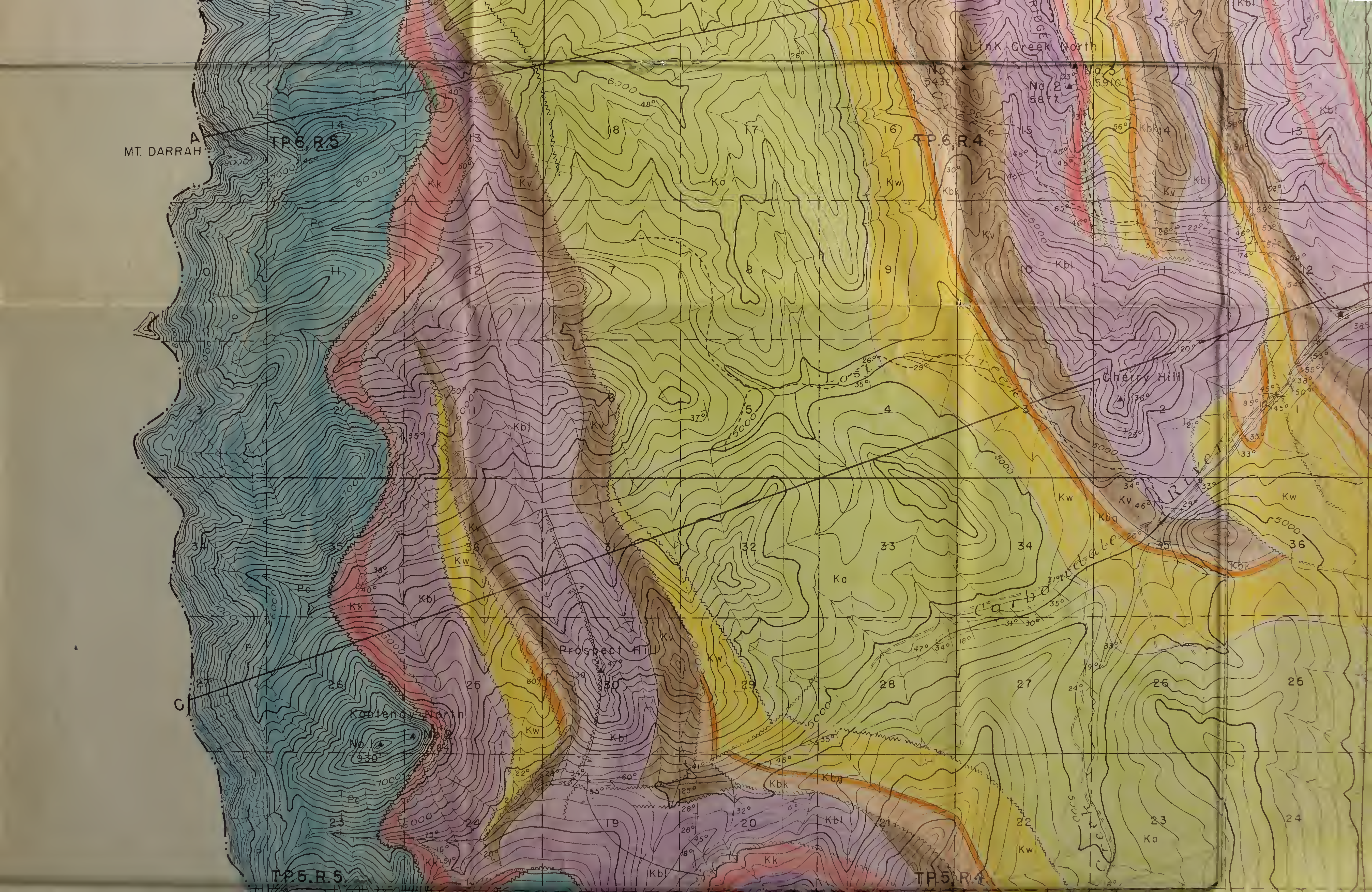
9000'
8000'
7000'
6000'
5000'
4000'
3000'
2000'
P
Pc
Kk
Kbl
Kv
Kbk
Ka
Kw
Link Creek
C
8000'
Kootenay North
Prospect Hill
Lost Creek
Cherry Hill
George Creek
P
Pc
Kk
Kbl
Kv
Kw
Jf
Kbk
Ka
114°30'
49°30'
26
25
30
29
28
27
26
25

Carbondale River
CARBONDALE HILL
Castle River
F
7000'
6000'
5000'
4000'
3000'
2000'
Kbl
Kbk
Kv
Kk
Jf
Link Creek
WILLOUGHBY RIDGE
George Creek
HASTINGS RIDGE
B
9000'
8000'
Kw
P
Webb Creek
D
3000
114°15'
49°30'
No.2 Byron
5618'


MT. DARRAH
TP.6, R.5
TP.6, R.4
TP.5, R.5
TP.5, R.4
Link Creek North
Cherry Hill
Prospect Hill
Kootenay North
Lost Creek
Carbondale
River
Kk
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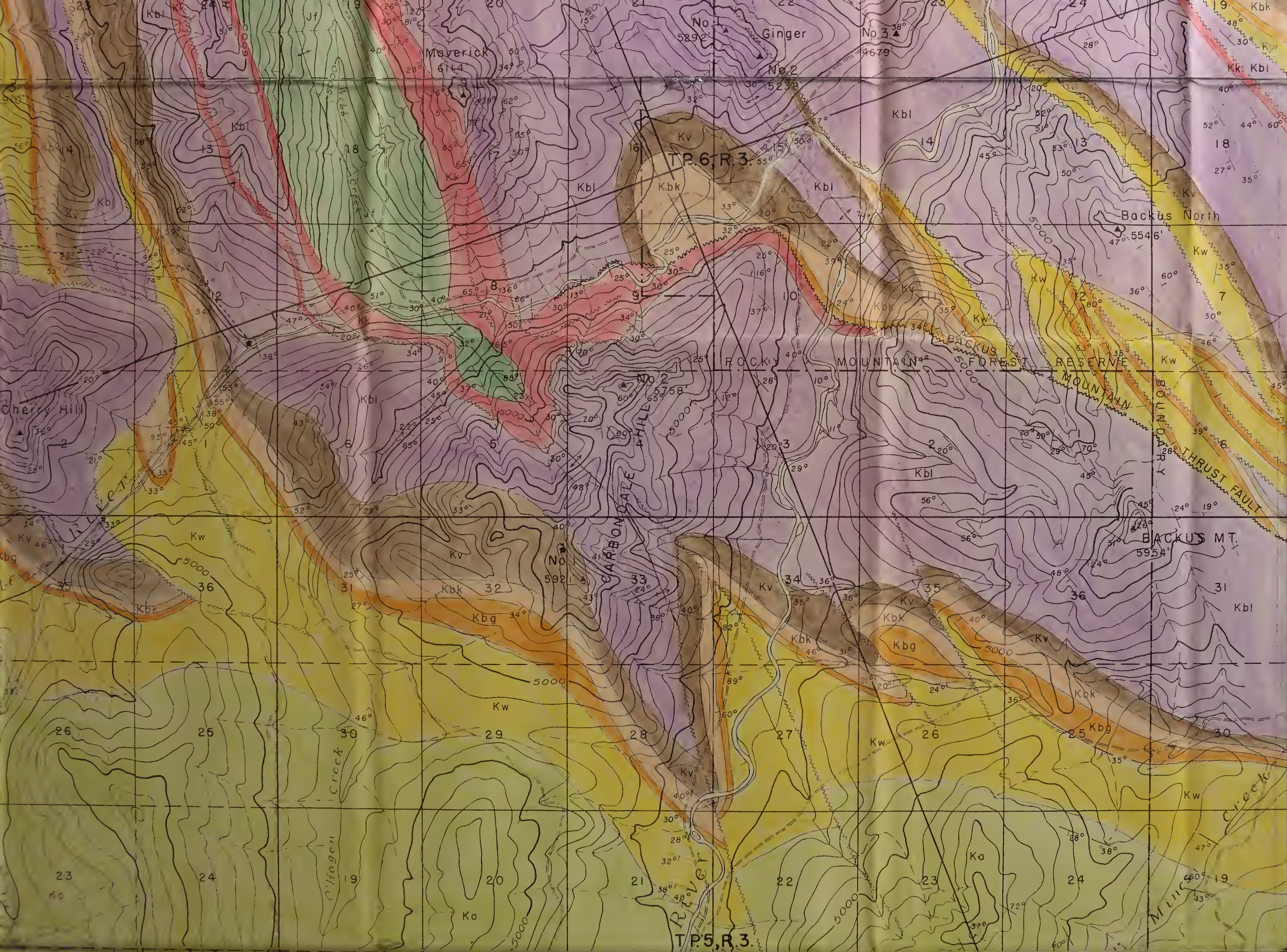

Maverick
6114'
Ginger
No. 2
5292'
No. 2
5238'
No. 3
4679'
TP. 6, R. 3.
Backus North
5546'
ROCKY MOUNTAIN FOREST RESERVE
BACKUS MOUNTAIN
BOUNDARY THRUST FAULT
No. 2
5758'
Cherry Hill
CARBONDALE HILL
No.
5921
BACKUS MT.
5954'
River
Creek
Hagen Creek
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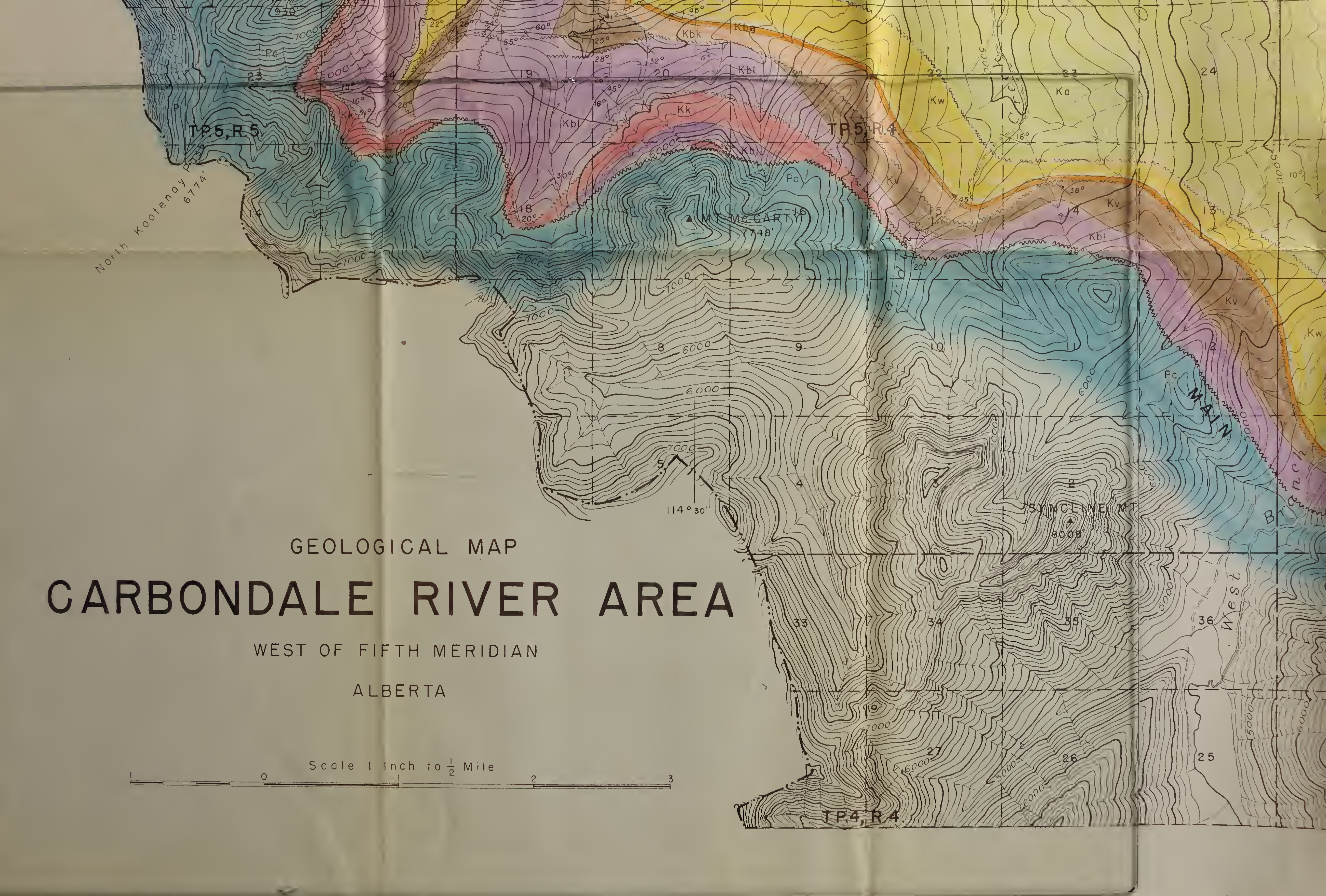
Kbl
Kk
Jf
Kv
Kbk
Kw
Kbg
Ko
5000



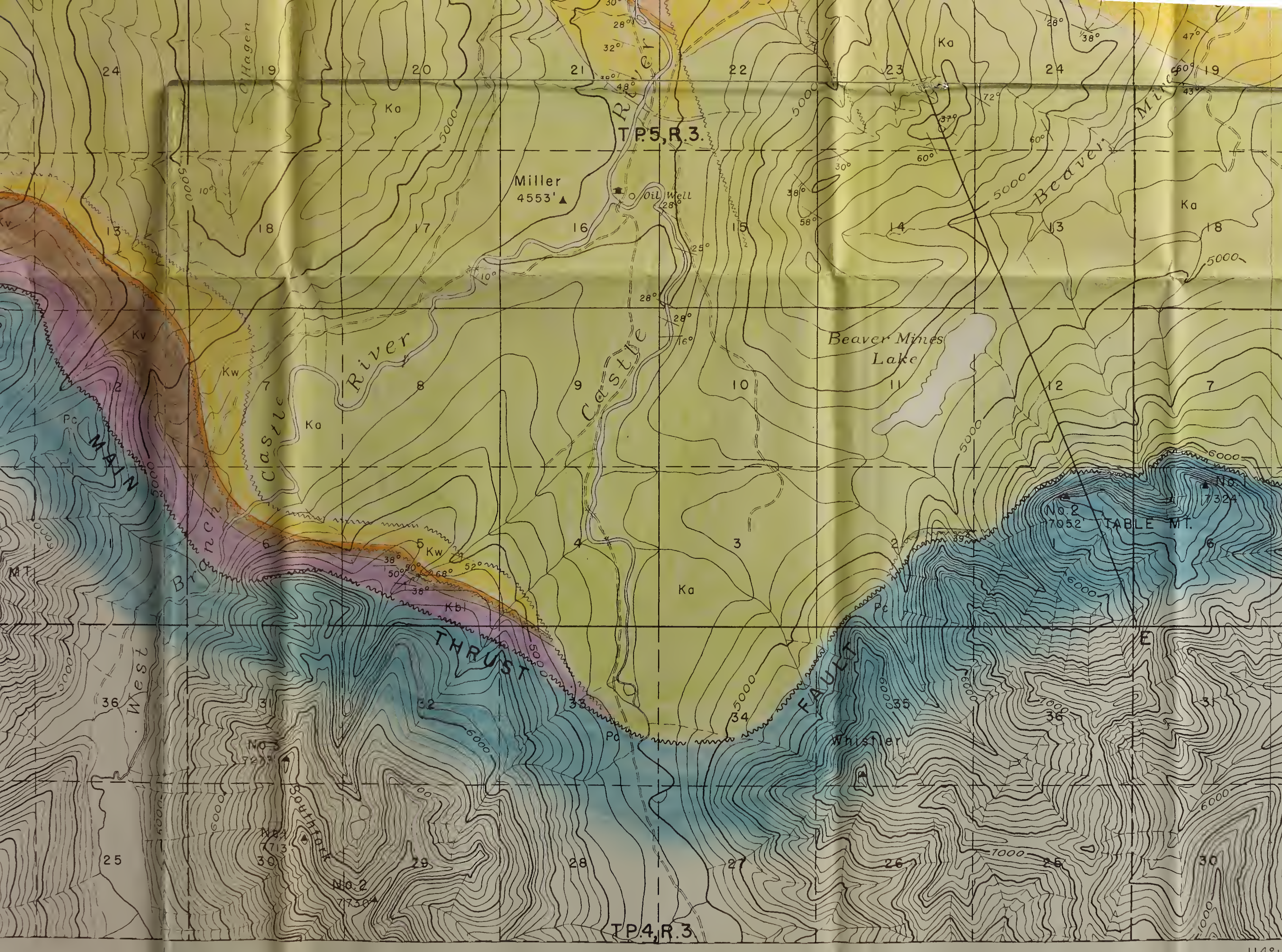
GEOLOGICAL MAP

CARBONDALE RIVER AREA

WEST OF FIFTH MERIDIAN

ALBERTA

LEGEND

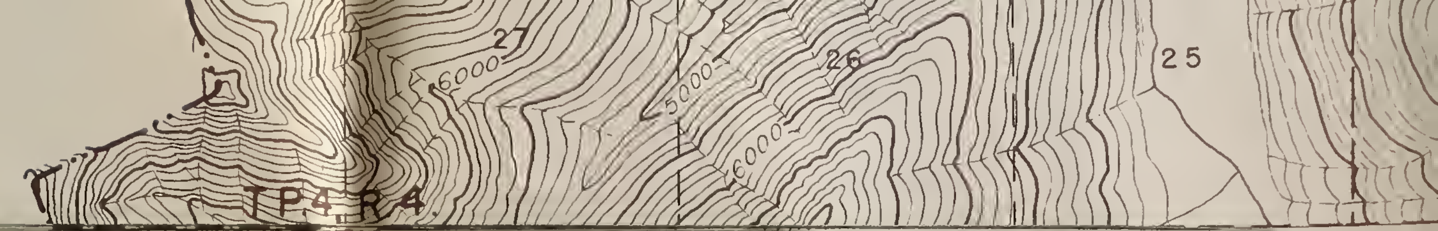


TP.5, R.3.
TP.4, R.3.
Miller
4553'
Oil Well
Castle River
Beaver Mines Lake
Beaver Mine
O'Hagen
MAIN THRUST FAULT
West Branch
South Fork
TABLE MT.
No. 1
7324
No. 2
7052'
Whistler
No. 2
7730
No. 1
7713
Ka
Kw
Kv
Kbl
Pc
114°15'

LEGEND

Scale 1 Inch to $\frac{1}{2}$ Mile

1 0 1 2 3



LEGEND

MESOZOIC

CRETACEOUS

UPPER CRETACEOUS

BEARPAW FORMATION: *black-gray sandy shales, carbonaceous layers; shell beds; marine and brackish water.*

Ka — ALLISON FORMATION: *soft greenish gray sandstone and shale; fresh and brackish water.*

Kw — WAPIABI FORMATION: *dark gray and black sandy shales; nodules, brown sandstone bands; marine.*

Kbg — BIGHORN FORMATION: *gray quartzite sandstone; dark gray shales with conglomeratic lenses; marine.*

Kbk — BLACKSTONE FORMATION: *gray and dark gray arenaceous shales, nodular, marine.*

LOWER CRETACEOUS

Kbl — BLAIRMORE FORMATION: *green, gray and maroon shales, green, gray, and greenish-gray sandstone, fresh water limestone, non-marine.*

Kk — KOOTENAY FORMATION: *brown, dark gray and black shales; coarse-to fine-grained gray sandstone, coal seams; non-marine.*

JURASSIC

Jf — FERNIE FORMATION: *black shale; gray and brown arenaceous shale; brown finely bedded sandstone; marine.*

PALEOZOIC

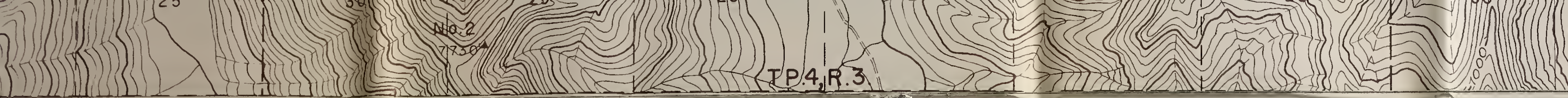
P — UNDIVIDED: *green shale; light gray dolomite, brecciated zone; gray limestone; calcarious shale; marine.*

PRECAMBRIAN

Pc — UNDIVIDED: *buff weathering limestone and sandstone; red and green argillite; lava flow and sill.*

LOWER CRETACEOUS

Kv — CROWSNEST FORMATION: *tuffs, agglomerates, breccias and bedded ash.*



LEGEND

shales. green.
er limestone:
ack shales;
l seams;
arenaceous
recciated zone;
ndstone. red

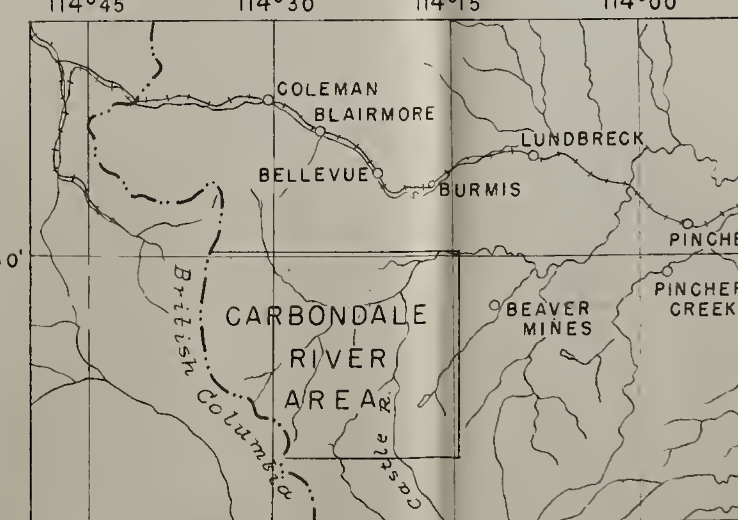
Geological boundary (approximate.)
Bedding (inclined, vertical, overturned)
Fault
Anticlinal axis
Synclinal axis
Coal mine
Road well travelled
Forestry trail
Bridge
Forestry cabin
Lookout station
Forest Reserve boundary
Township boundary (surveyed.)
Township boundary (unsurveyed.)
Section line (surveyed.)
Section line (unsurveyed.)
Intermittent stream
Contours (interval 100 feet.) 5000
Height in feet above mean sea-level 7052'

Base map compiled from surveys of the Topographical Survey of Canada.

PLAN OF TOWNSHIP

31	32	33	34	35	36
30	29	28	27	26	25
19	20	21	22	23	24
18	17	16	15	14	13
7	8	9	10	11	12
6	5	4	3	2	1

INDEX MAP



SCALE 1 INCH TO 10 MILE

To Accompany Thesis of W.H.A. CLOW March, 1950.

B29758